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TECHNICAL REPORT
NATICK/TR-77/025

TEXTURED PLANT PROTEINS USED AS EXTENDERS: TYPES PROCESSING, PROPERTIES, NUTRITIONAL VALUE, ACCEPTABILITY: AN ANNOTATED BIBLIOGRAPHY

Project Reference: 1T762724AH99

April 1978

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UNITED STATES ARMY
NATICK RESEARCH and DEVELOPMENT COMMAND
NATICK, MASSACHUSETTS 01760

Food Engineering Laboratory
FEL-74

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER Natick/TR-77-025	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) TEXTURED PLANT PROTEINS USED AS EXTENDERS: TYPES, PROCESSING, PROPERTIES, NUTRITIONAL VALUE, ACCEPTABILITY: AN ANNOTATED BIBLIOGRAPHY		5. TYPE OF REPORT & PERIOD COVERED Technical 6. PERFORMING ORG. REPORT NUMBER FEL-68
7. AUTHOR(s) Carol P. Shaw and John L. Secrist		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Natick Research & Development Command Natick, Massachusetts 01760		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 6.2 1T762724AH99
11. CONTROLLING OFFICE NAME AND ADDRESS Commander US Army Natick Research & Development Command ATTN: DRXNM-WTA, Natick, Mass. 01760		12. REPORT DATE April 1978 13. NUMBER OF PAGES 150
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

PLANT PROTEIN
PLANTS (BOTANY)
PROTEINS
TEXTURED PLANT PROTEINS
MILITARY RATIONS
NUTRITION
SOY PROTEINS
SOYBEANS
SOYBEAN TECHNOLOGY
FABRICATED FOODS

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A literature review was undertaken on textured plant proteins used as extenders to summarize the recent experimental work on various types of plant proteins as published in the major United States technical journals from 1972 through September 1976. An abstract or summary of each reference is included.

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PREFACE

It is well known that the addition of textured plant proteins can be used to extend ground beef and other food products at a reduced cost. Earlier evaluations undertaken by NARADCOM as reported in Technological Reports No. 75-80 FEL and No. Natick/TR-77/020 and included in this bibliography, have indicated that levels up to twenty per cent of high quality soy protein could be used in ground beef in military subsistence.

However, it was also found that there was a large variation in the flavor of different brands of soy products. Under the military procurement system where the contract goes to the low bidder and whereby the lower cost products are more often apt to retain objectionable cereal flavors, the chances of the military obtaining low quality textured plant proteins are very real.

Project Number 1T762724AH99 was initiated not only to further assess the feasibility of utilizing textured plant proteins in military rations, but also to provide methods and procedures to identify qualitative and quantitative paraments of various textured plant proteins.

The first step of this project, and the subject of this report, was to conduct a literature search on the use of plant proteins as extenders in food products. Funding of this project was discontinued upon completion of the literature review.

The authors wish to thank the NARADCOM library staff for their assistance in locating certain material pertinent to this review.

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INTRODUCTION

Extensive investigations have been made in the field of textured plant proteins. It is the purpose of this report to summarize the recent experimental work on various types of textured plant proteins as published in the major technical journals in the United States.

In 1954, Mr. R.A. Boyer (U.S. Patent 2,682,466) developed a process for the texturization of plant proteins. Adaptations and refinements of his techniques have led to the use of texturized plant proteins as extenders. The use of these extenders has spread (widely) throughout the meat, poultry, and seafood industries. Although other food products may contain texturized plant proteins, the primary reasons for their use have been for nutritional or other functional purposes.

The texturization process is most widely used in the soy products, but the possibilities and indeed the probabilities of expanding the market by use of other plant proteins is being widely researched. This bibliography contains abstracts and summaries of research in both soy and non-soy plant proteins. No attempt was made to research material on forms of protein extenders other than those derived from plant products. Thus, research on casein, whey, single cell proteins, beef tissues and by-products, fish meal, etc., are not included in this report. However, plant proteins that have the potential of being texturized are included.

This report summarizes the literature on texturized plant proteins found mainly in the major United States technical food journals from 1972 through September 1976. The reasons for using this time frame are twofold. In almost all instances the abstract is quoted directly as written, but in a few abstracts minor modifications, such as eliminating abbreviations were made for clarity.

November of 1973 a World Soy Protein Conference was held in Munich, Germany. Many informative papers were presented at this conference, including one by W.J. Wolf entitled "Soybeans: Their production, properties and food uses. A Selected Bibliography". Anyone desiring to investigate earlier work on soybean technology is advised to read this and other proceedings of the conference which can be found in the Journal of American Oil Chemists Society, January 1974, Volume 51:1. The second reason for using this time frame is because in-depth investigations with textured plant proteins other than soy are relatively recent.

OUTLINE

The references in this report are grouped by subject. Each entry under a subject heading includes an abstract or summary of the paper. When a journal printed an abstract, a copy follows the entry; when no abstract was available, a summary of the paper was prepared by the editors of this bibliography to describe the entry. An alphabetical cross index by author lists all the papers cited to show page location of abstract or summary.

The method of organizing the references is as follows:

I. Reference books on textured plant proteins. The following books are valuable in providing a general knowledge of textured plant proteins and their use as extenders.

1. Altshul, A.M. ed. 1974. New Protein Foods: Technology 1A, Academic Press, Inc. New York, N.Y. 521 pp.

Summary: This book is divided into ten chapters written by various authors who are noted authorities in their fields of specialization. The book offers an overview of protein sources and the technology for transforming these proteins into more usual sources. Although most of the book is very general in terms of types of proteins (cereals, legumes, baked products, meat, etc.), it does discuss the new technologies of protein processing and the commercial development, nutrition, and marketing aspects of plant protein products as extenders. Volume 2[1] of this book has recently been published and conerns itself largely with new protein sources.

2. Friedman, M. ed. 1975. Protein Nutritional Quality of Foods and Feeds, Volume 1 Part 2: Quality Factors - Plant Breeding, Composition, Processing and Anti-Nutrients. Marcel Dekker, Inc., New York, N.Y. 696 pp.

Summary: This contains the second part of the Proceedings of the American Chemical Society's 1974 Symposium on Chemical and Biological Methods for Protein Quality Evaluation. In this volume (Part 2) 55 authors prepared 26 chapters. Covered are such topics as evaluations of nutritional quality of various plant proteins and concentrates, the effects of processing on the nutritional value, the effects of enzymes and anti-nutritional factors, and the problem of flatulence. Part 1 of this Volume 1[2] concerns itself with protein assay methods.

3. Gutcho, M. 1973. Textured Foods and Allied Products. Noyes Data Corporation, Park Ridge, New Jersey 225 pp.

Summary: This Noyes Data publication is based on U.S. Patents since 1960 that relate to the preparation of textured foods and allied products. It covers spun fiber processing in detail as well as other techniques for obtaining meat-like textures.

1 Altshul, A.M. ed. 1976 New Protein Foods, Vol 2, Technology, Part B

2 Friedman, M. ed, 1975 Protein Nutritional Quality of Foods and Feeds, Volume 1, Part 1. Assay methods - Biological, Biochemical and Chemical.

4. Hanson, L.P., 1974. Vegetable Protein Processing, Noyes Data Corporation, Park Ridge, New Jersey 308 pp.

Summary: This book is a review of the patent literature relating to the processing of vegetable proteins, some of which are being used commercially, others not. It provides an overview of the technology of

(1) general processes for vegetable proteins

(2) processing of various soy products

(3) cottonseed proteins

(4) grain proteins

(5) other vegetable proteins.

There are also chapters on extruded and other fiber processing methods, textured protein gels, and expanded products as well as a chapter on consumer products.

5. Inglett, G.E. ed. 1975. Fabricated Foods, Avi Publishing Co., Inc., Westport, Conn. 215 pp.

Summary: Fabricated Foods is comprised of selected papers from a short course on Fabricated Foods sponsored by the Agricultural and Food Chemistry Division of the American Chemical Society and conducted at Las Vegas, Nevada, March 27-29, 1974. The definition of fabricated foods in this publication is "foods that have been designed, engineered, or formulated from various ingredients including additives." Foods extended with textured plant proteins are thus considered fabricated foods. The book gathers together papers covering such topics as government regulations, marketing aspects, physicalchemical principles, soy proteins, textures by extrusion processing, flavorings, and nutritional aspects of fabricated foods.

6. Inglett, G.E. ed. 1972. Symposium: Seed Proteins, Avi Publishing Co., Westport, Conn. 320 pp.

Summary: Contained in this book are the proceedings, with additional papers, of the Symposium of Seed Proteins held at the American Chemical Society's meeting in Los Angeles, March 28- April 2, 1971. The chapters are divided into five sections dealing with General Outlook, Protein Synthesis in Seeds, Protein Quality and Quantity, Seed Processing, and Product Properties and Methodology. Almost all major seeds are dealt with, and particular emphasis is placed on wheat, corn, soybeans, rice, barley, oats, peanuts, and cottonseed.

7. Karmas, E. 1975 "Processed Meat Technology" in Food Technology Review, No. 33. Noyes Data Corporation, Park Ridge, New Jersey, Chapter 11.

Summary: This chapter summarizes the patent literature on ground meat patties and spun protein fibers.

8. Murti, K.S. and Achaya, K.T. 1975. Cottonseed Chemistry and Technology, Publications and Information Directorate, No. 598, CSIR, New Delhi, India, 348 pp.

Summary: While certain chapters of this book deal with cottonseed in India, the treatment of technological and chemical subjects are based on world information. The book covers all aspects of cottonseed chemistry and includes basic processing information on cottonseed meal, cake, flour and other cottonseed products of interest.

9. Pirie, N.W., ed. 1975. Food Protein Sources, Cambridge University Press, Cambridge, London, New York, Melbourne 260 pp.

Summary: Twenty-five papers are compiled in this book as a result of knowledge shared under the International Biological Programme from 1964-1974. The papers offer a comprehensive review of various protein sources, their present and potential uses. The book is divided into four parts: (1) Sources edible after minimal processing, (2) Concentrates made by mechanical extraction, (3) Concentrates made by biological conversion, and (4) The use of novel foods.

10. Smith, S.J. and Circle, A.K., eds. 1972. Soybeans: Chemistry and Technology Volume I, Avi Publishing Co., Westport, Conn.

Summary: This volume reviews the research and development of food uses of proteins during the past twenty years. It also includes chapters by various authors on such topics as nutritional value; processing for flours, concentrates and isolates; chemical composition; and genetic characteristics.

11. Wolf, W.J. and Cowan, J.C., revised 1975. Soybeans as a Food Source, CRC Press, Inc. Cleveland, Ohio, 86 pp.

Summary: This book is a revision and update of the first edition which was published in 1971. The first 69 pages are identical to the first edition which is a basic explanation of soybean production, processing, usage, and functional properties. The new material occurs as an addendum of twenty pages. A very valuable part of this edition is the updated literature review-- from 1971 to 1974.

II. General References on Textured Vegetable Proteins.

In compiling a reference list of papers on textured plant proteins, one finds many general articles dealing with the texturization process, the current use, projected usage, characteristics, manufacturers, government regulations, economic impact, nutritional value, consumer acceptance, etc. of plant proteins in general. Following is a list and summary or abstract of articles relevant to the overall textured plant protein field.

1. Adolphson, L.D. and Horan, F.E. 1971. Textured vegetable proteins as meat extenders. Cereal Sci. Today 19:10, 442-446.

<u>Summary</u>: In 1973, over a 30-week period, soy-ground beef accounted for 20%-25% of ground beef sales. In 1974 the marketing climate had changed due to greater meat availability and lower prices. The educational steps in the development of markets are discussed. In order for commerical manufacturers to have a common goal in the development of novel protein systems, such as textured vegetable protein products, a number have joined to form the Food Protein Council. Subcommittees include (1) Domestic Regulatory Affairs, (2) Scientific, (3) Traffic and Transportation, (4) Public Relations, and (5) International Regulatory Affairs.

2. Altschul, A.M. 1974. Vegetable proteins in prudent diet foods. Food Technol. 28:1, 24-26.

<u>Summary</u>: Currently, the major source of vegetable protein in animal food analogs is soy protein. There is reason to believe that other vegetable or microbial sources of protein, such as wheat gluten and yeast, could also be used extensively. Products containing no cholesterol, lower quantities of fat, and about equal PER* ratios are available now, and by 1980 it is expected that they will replace 10 to 20 per cent of the meat items in the American diet. Soybean protein has more lysine than necessary for balanced protein nutrition and thus is an effective supplement for lysine-deficient cereals. The soybean is deficient in methionine and, in this case, cereals provide the complement. It is possible to define the parameters of soy products so that the shift from meat to soy does not diminish the nutrients obtained from meat products. However, the problem of unknown micronutrients present in meat and not in soy and other vegetable protein products must be solved. The best defense against the unknown in nutrition is to strive for the greatest variety and diversity in foods. This also means broadening the base of raw materials in fabricated foods that serve as meat analogs.

* PER = protein efficiency ratio

3. Bird, K.M. 1974. Plant proteins in USDA feeding programs. Cereal Sci. Today 19:6, 226-230.

Abstract: Plant proteins play an increasingly important role in the food system of the U.S. Substantial cost advantages are offered by these new food forms. At current meat and soy prices, a cost savings of about $5 million a year is possible to schools. A substantial growth is projected in this market for the next decade. Textured vegetable proteins, at present entirely derived from soybeans, have been used in school lunch programs for 2 years and have a volume of over 9 million pounds (dry weight) annually. Other sources of plant protein that may see advances include cottonseed, peanuts, safflower seed, sunflower seed, and grains. Plant proteins are being used to fabricate foods similar to those that are familiar to people. In USDA programs, plant proteins are blended with other foods, and the combination results in foods that have a better balanced amino acid pattern than if these foods were used alone. The Food and Nutrition Service of the U.S. Department of Agriculture has set up a system for evaluating, accepting, listing, and monitoring plant proteins being used in its several feeding programs.

4. Bird, K.M. 1975. Plant proteins: Their role in the future. J. Am. Oil Chem. Soc. 52:4, 240A-241A.

Abstract: Schools in the U.S. used about 60 million pounds of hydrated textured vegetable protein in 1973-74 compared with 40 million pounds in 1972-73 and 28 million pounds in 1971-72. Plant proteins are projected to replace about 2,146 million lb meats and other proteins in the U.S. by 1980.

5. Bird, K.M. 1974. Plant Proteins: Progress and Problems. Food Technol. 28:3, 31-39.

Summary: The United States is entering a transition period in which the U.S. food economy will shift from predominantly animal based protein to plant based protein. Examples of this trend (school lunch programs, institutional feeding, needy family programs, etc.) are given. Certain questions should be answered to make this a smoother and more orderly change: standards, labelling, prejudices, etc. The Economic Research Service prediction is that by 1980 21 billions of pounds of processed meats will contain some plant proteins and that hydrated plant proteins will comprise 17 per cent of processed meat.

6. Bloom, G.F. 1974. Will consumers buy your fabricated protein? Food Engineering 46:5, 100-101.

Summary: The future looks promising for textured protein extenders and analogs, but is dependent on several factors such as selling good nutrition, consumer attitudes, cost, performance, packaging, labelling, distribution, and other attributes. Careful control is needed when extenders are added so that the optimum level of extender is used.

7. Breene, W.M. 1976. Problems in determining textural properties of textured plant proteins. Presented at the 36th Annual Meeting of the Institute of Food Technologists. Anaheim, California, June 6-9, 1976.

Abstract: Textured plant protein (TPP) products manufactured by extrusion-expansion or compaction of soy flour comprise the largest class of such products. Principal usage is in the extension of ground beef; annual usage of 1 billion pounds by 1990 has been predicted. The products contain slightly more than 50% protein and vary considerably in their physical properties. Establishment of a meaningful standard of identity or common or usual name for these products will require their characterization by a suitable instrumental procedure. The only objective test now being widely used for such characterization is the Food and Nutrition Service (FNS) Category 1 test used to evaluate products for use in the School Lunch Program; it does not directly measure textural properties such as tenderness, toughness, juiciness, etc. The Minnesota Texture Method (MTM) appears to have promise. The potential of the MTM or other instrumental methods for use in characterizing the textural properties of TPP must be investigated.

8. Brian, R. 1976. Texturized Protein Products. J. Am. Oil Chem. Soc. 53:4, 325-326.

Abstract: Texture is changed in oilseed protein fractions by mechanical and chemical means in specialized equipment. Processing conditions are closely controlled to ensure end product forms wanted. The arrangement of equipment used in the production of textured proteins is discussed as it relates to a commercial plant design. The nature of feed materials and details of processing conditions required to produce texture in soy protein are presented. Other forms of textured oilseed protein are discussed.

9. Coleman, R.J. 1975. Vegetable Protein a delayed birth. J. Am. Oil Chem. Soc. 52:4, 237A-239A.

Abstract. Manufacturing technology related to vegetable protein is ahead of its marketing counterpart. Communication among technical, marketing, and consumer groups is required if formed vegetable protein is to succeed as a foodstuff. Perhaps the final status of vegetable protein will be determined by how well these communication lines are established.

10. Hammonds, T.M., and Call, D.L. 1972. Protein use patterns, current and future, Chemical Technol. 2:3, 156-162.

Summary: A maximum market potential for protein ingredients is estimated at 3.1 billion pounds. Soy protein is expected to compete largely with nonfat dry milk. The ranking for the most desirable meat extenders was: extruded protein, first; spun protein, second; and flour or grits, third. Canned and processed meats are believed to offer the most growth potential of all product categories. Undesirable product taste is ranked as the most limiting factor in consumer acceptance. The Rand DELPHI technique was used with an 18-member panel of management and research people from the meat and soybean industries to project trends in protein usage.

11. Happich, M.L. 1975. Protein nutritive value of selected present and potential meat extenders in Friedman, M., editor. Protein Nutritional Quality of Foods & Feeds, Vol. #1, Part 2, Marcel Deker, New York, N.Y., pp. 161-185.

Summary: The protein nutritive value of partially defatted chopped beef, partially defatted beef tissue, and other beef by-products are discussed. The protein efficiency ratios (PER) were determined for the proteins of whey, fish, soy, and liquid-cyclone-process protein concentrates, individually and in combination with lean beef. All the combinations had PER values equal to or higher than 2.5 (PER value for casein).

12. Johnson, D.W. 1976. Oilseed Vegetable Protein Concentrates. J. Am. Oil Chem. Soc. 53:6, 321-324 pp.

Abstract: Soy protein concentrates are articles of commerce in the U.S. and other areas of the world. The procedures for producing these products involve processes where the protein is "immobilized" by various procedures, whereby soluble materials such as carbohydrates, mineral matter, and other water or alcohol soluble constituents are removed. There have been four general procedures which have been used commercially, but recently a fifth procedure involving what might be referred to as a "triple" solvent procedure has been developed. While the commercial products available, at least in the U.S., are from soy, development work has been carried out to produce concentrated products from peanut, sunflower, sesame, and rapeseed. However, there are no commercial installations for producing protein concentrates from these oilseeds. A brief discussion of the various processes is presented.

13. Kakade, M.L. 1974. Biochemical basis for the differences in plant protein utilization. J. Agric. Food Chem. 22:4, 550-555.

Abstract: The biological utilization of protein depends upon factors such as protein content, protein quality, and protein digestibility. Amino acid(s) deficiency or excess, which is exaggerated at low protein intake, affects protein utilization by either limiting the amino acid(s) for tissue protein synthesis or by creating an extra burden on liver and kidney for degradation of the excessive amino acid(s). The digestibility of protein is considerably influenced by the presence of enzyme-resistant peptides and enzyme-inhibiting substances. The structural features and amino acid sequence of proteins may also influence the availability of amino acids. For example, the protein component of many plant foodstuffs with high cystine content has been found to be refractory to attack by trypsin, an affect which is attributed to the stability of the molecule produced by a large number of disulfide bonds. Other specific examples and data on the subject matter are presented and discussed.

14. Kinsella, J.E. 1976. Functional properties of proteins in food science and nutrition. CRC Critical Reviews in Food Science and Nutrition. 7:3, 219-280.

Abstract: Proteins for foods, in addition to providing nutrition, should also possess specific functional properties that facilitate processing and serve as the basis of product performance. Functional properties of proteins for foods connote the physiochemical properties which govern the behavior of protein in foods. This general article collates the published information concerning the major functional properties of food proteins, e.g., solubility, binding properties, surfactant properties, viscogenic texturizing characteristics, etc. The effects of extraction and processing on functional properties and possible correlations b etween structure and function are discussed, in relation to practical performance in food systems. Modification of proteins to improve functional characteristics is briefly mentioned. A comprehensive reference list is included.

15. LeSieur, Special Report First International Food Congress highlights. 1976. Food Processing 37:11, 24-30.

Summary: The First International Congress on Engineering and Food held in Boston, Aug 9-13, 1976 opened with a keynote speech by Dr. Nevin Scrimshaw of MIT. It was his view that the major emphasis should be on protein sources, properties, and technology. This should include genetic recombinance, asexual reproduction, production of single cell protein, texturized protein concentrates, isolates and meat analogs from soy and other oilseeds. Whey products, aquatic sources, such as krill, kelp, and trash fish may be used. Leaf protein provides the most abundant source. In New Zealand, Ruakura Agricultural Research Center has recovered from grass 47% unfractionated protein concentrate or 11% for cytoplastic protein fraction suitable for human consumption.

16. Lin, M.J.Y., Humbert, E.S., and Sosulski, F.W. 1975. Quality of wieners supplemented with sunflower and soy products. Can. Inst. of Food Sci. and Tech J. 8:2, 97-101.

Abstract: Six experimental lots of wieners w ere prepared, which contained soy flour, soy concentrate, sunflower flour, two sunflower concentrates diffusion extracted at 60°C (DE-60) and at 80°C (DE-80), and a sunflower pH activated DE-60 concentrate. Sufficient soy and sunflower products were added to commercial wiener mixes to increase the protein content from 12% in the control commercial samples to about 14% in the protein-supplemented wieners. The sausage emulsions were evaluated by emulsion stability; the processed wieners were judged according to shrinkage, color, peelability, firmness and cooking properties while the quality of the cooked wieners was determined by their organoleptic characteristics. Although the cooked control samples were judged slightly higher in organoleptic quality than the vegetable protein supplemented products, the wieners containing the soy additives and the sunflower DE-60 and activated DE-60 concentrates were not considered to be as satisfactory due to the developments of softened texture and heated flavor, respectively. Simple correlations were calculated between functional properties of vegetable proteins and certain characteristics of the wieners.

17. Lockmiller, N.R. 1972. What are textured protein products? Food Technol. 26:5, 56-58.

Summary: The differences between soy grits and flour, soy concentrates, soy isolates, and textured vegetable proteins are explained. The two main types of textured vegetable proteins, the expanded vegetable proteins and the spun vegetable proteins, are described.

18. Maga, J.A., Lorenz, K., and Onayemi, O. 1973. Digestive acceptability of proteins as measured by the initial rate of in vitro proteolysis. J. Food Sci. 38:1, 173-174.

Abstract: A study was undertaken to measure the initial rate of proteolysis with trypsin of some commonly used protein sources (sodium caseinate, defatted peanut flour, defatted cottonseed flour, fish protein concentrate, and isolated soy proteinate) as a sample in vitro means of measuring gastronomic acceptability. Although differences among proteolysis rates were found, in all products proteolysis occurred in the first few minutes and then remained constant. Sodium caseinate was by far the most easily digestible protein source evaluated; isolated soy proteinate was the least digestible followed by fish protein concentrate, defatted cottonseed flour, and peanut flour. Steaming resulted in faster hydrolysis rates. The conclusion is that although certain vegetable proteins may have high nutritional and biochemical values, their digestive acceptability may be quite poor since they are not rapidly hydrolyzed in the digestive system.

19. Rosenfield, D. 1976. The changing climate for plant protein foods: 1965-1976. Cereal Foods World 21:7, 302-306.

Summary: The milestones of plant protein use are outlined as: (1) AID Commercial Protein Foods Studies Program, (2) General Mills Bac-O's Venture, (3) Textured Proteins for School Lunch Program, (4) Meat-Soy Retail Market Mixtures, (5) World Soy Protein Conference, (6) National Marketing by Miles Laboratories of Morningstar Farms Analogs.

20. Schutz, H.G. 1974. Textured protein: Consumer acceptance and evaluation considerations. Cereal Sci. Today. 19:10, 453-457.

Summary: Textured proteins are excellent examples of a product in which all the aspects of food acceptance operate. Worthy of testing is the "extended use" test in which consumers can evaluate textured proteins over a period of time and under a variety of conditions and use.

21. Smith, G.C., Juhn, H., Carpenter, Z.L., Mattil, K.F., and Cater, C.M. 1973. Efficacy of protein additive as emulsion stabilizers in frankfurters. J. Food Sci. 38:5; 849-855.

Abstract: Frankfurters of four different fat contents were prepared using only meat (control) or meat plus 3.5% of eleven kinds of protein additives. Protein additives were of low (LNS) or high (HNS) nitrogen solubility and included: soy protein isolates (LNS and HNS), soy protein concentrates (LNS and HNS), soy flours (LNS and HNS), glandless cottonseed flours (LNS and HNS), cottonseed protein concentrate (LNS), nonfat dry milk (HNS), and fish protein concentrate (LNS). None of the functional properties or characteristics of the protein additives were closely related to their performance in stabilizing emulsions when utilized at the 3.5% level. Nitrogen solubility index was significantly correlated with water-holding capacity but was not related to other functional properties of protein additives. Higher emulsion stability was not always indicative of more desirable appearance in frankfurters. The protein additives had little or no effect on emulsion stability among frankfurters of low fat content (24-26% fat). When frankfurters were prepared to contain 34-35% fat, soy protein concentrate (LNS) and fish protein concentrate (LNS) increased emulsion stability and decreased fatting-out. Microscopic studies suggested that these latter two protein additives affected emulsion stability by their contribution in forming three-phase emulsions in which the protein additives, as solid particles, attached to oil droplets and lowered the interfacial contact between the internal and external phases.

22. Smith, Oak B. Textured Vegetable Proteins, talk given at World Soybean Research Conference, University of Illinois, Aug 3-8, 1975.

Summary: The extrusion process for producing meat extenders and analogs is described, and advantages and disadvantages of extrusion-produced meat extenders are covered. This is a good basic reference source for understanding the extrusion process.

23. Smith, Oak B. Textures by Extrusion Processing, Prepared for Delivery in Short Course for Fabricated Food - Las Vegas, Nevada, Mar 28, 1974, Am. Chem. Soc., Div. of Agriculture and Food Chemistry.

Summary: A review of extrusion cooking is made, including the methodology of high temperature, short time extrusion-cookers, advantages and disadvantages of extrusion-cooking, control of process variables to affect textural properties, flatulence in fabricated plant protein foods, and control of textural requirements.

24. Stephenson, M.G. 1975. Textured plant protein products: New choices for consumers. FDA Consumer. Volume 9:4, 18.

Abstract: As meat prices soared, consumers were quick to discover the combinations of ground beef and textured plant protein offered in some supermarkets at several cents a pound less than regular ground beef. Many more products made from plant sources that can be combined with or substituted for animal products have begun to appear on the consumer market. Processing of these plant proteins is described. FDA is preparing regulations requiring

that the plant protein components in a food be prominently identified on the principal display panel of food labels; these descriptive terms represent a new vocabulary for most consumers. Nutritional qualities of the various products are discussed with used and preparation tips.

25. Terrell, R.N. and Staniec, W.P. 1974. Meat and non-meat protein combinations in comminuted mixes - Doing more with less-, talk presented at the 16th Annual Meat Science Institute, U. of Georgia, Feb. 24, 1974.

Summary: The ramifications of using alternative protein sources is discussed, emphasizing the economical, functional, manufacturing, nutritional and labeling aspects, their costs and their complexity. The conclusion is that "if we use what we have (i.e., established food sources) better," the industry can produce more economical, and equally nutritious products, which are popular, and have readily acceptable consumer markets.

26. Trauberman, L. 1974. Planning ahead for low cost protein. Food Engineering January, 1974. Volume 46:1, 70-72.

Summary: With animal protein in short supply, the development of new protein sources and technology must be accelerated. Soybean has become acceptable, cottonseed has become commercially acceptable as a 65% protein; flour and peanut flour with about 57% protein may soon be another source. Other potential sources are oat protein (has the best amino acid balance), corn protein (although now not as pure, light colored, or bland as desirable), sunflower seeds (processed to prevent darkening or green color), coconut protein (available from England), and rapeseed protein.

27. USDA, 1971 FNS Notice 219. Textured Vegetable Protein Products (B-1) to be used in combination with meat for use in Lunches and Suppers Served under Child Feeding Programs. FNS Notice 219 Attachment, Textured Vegetable Protein Products (B-1).

Summary: Specifications are given for use of textured vegetable protein products in the National School Lunch program. Ratio of hydrated vegetable protein (moisture content 60%-65%) to uncooked meat, poultry or fish in the combination shall not exceed 30 parts to 70 parts, respectively, on basis of weight. PER value of the textured vegetable protein shall not be less than 1.8.

28. USDA, Food and Nutrition Service, Sept 1974. Acceptable Textured Protein Products.

Summary: This publication specifies the following:

I. Companies producing and/or distributing under private label brands of textured vegetable proteins that meet the requirements of FNS Notice 219.

II. Information of labeling acceptable textured vegetable protein products.

III. Textured vegetable protein mixes.

IV. Procedure for processors and private label distributors to have their names and brands included on the list of acceptable products.

29. Vemury, M.K.D., Kres, C. and Fox, H.M. 1976. Comparative protein value of several vegetable protein products fed at equal nitrogen levels to human adults. J. Food Sci. 41:5, 1086-1091.

Abstract: The objective of the current study was to determine the protein nutritional value of several vegetable protein products processed to resemble ground beef. The test products were soy protein products, each made by slightly different extruded methods of industrial processing using basically either the defatted soy flour or the soy concentrate protein and a blended wheat protein product. Ground beef and dried whole egg were used as comparative control proteins. The human metabolic study was 32 days in length. Nine subjects were fed 4.0 g N from the test products plus 0.8 g N from the basal diet. Caloric intake was adjusted to maintain normal body weight. The test products were assigned at random. The protein nutriture of the subjects was evaluated by the nitrogen balance technique. Fasting venous blood samples were taken at the beginning and end of each experimental period. Results showed that the mean nitrogen balance of subjects fed extruded defatted soy flour protein, extruded soy concentrate protein and blended wheat protein products were -1.16, -1.31 and -0.99, respectively, as compared to the standard controls beef and egg, which were -0.42 and -0.34, respectively. There was a significant difference in the nitrogen balance of the standard controls and the test products but not among them. Wheat protein product which was supplemented with lysine had significantly better apparent digestibility than the soy protein products. Mean blood constituent data show that all values of all subjects were within the normal range throughout the study with the exception of triglyceride for a few individuals. The egg diet resulted in a significant rise in the blood triglyceride levels over values when other diets were fed. Blood cholesterol values tended to be higher when egg, beef, or normal diets were fed than when the vegetable protein diets were consumed.

30. Woodham, A.A. 1973. The effects of processing on the nutritive value of vegetable protein concentrates. The Proceedings of the Nutrition Society 32:5, 23.

Abstract: The effects of processing on the following protein isolates and textured proteins designed for human consumption are discussed: soybean meal; groundnut (peanut) and cottonseed meals: cruciferous oilseeds (rapeseed, mustard seed, and crambe seed): textured vegetable protein; and leaf-protein concentrate. Chemical methods of protecting protein quality are reviewed.

31. Wu, Y.V. and Inglett, G.E. 1974. Denaturation of plant proteins related to functionality and food applications. A Review, J. Food Sci. 39:2, 218-225.

Abstract: Proteins can be denatured by heat, changes in pH, organic solvents, detergents, urea, guanidine hydrochloride or other methods that modify the secondary, tertiary or quaternary structure, without breaking any covalent bonds. Physical-chemical measurements or functionality related to denaturation include solubility, viscosity, dissociation into subunits, sedimentation constant, optical rotation association and ultraviolet spectra. The relationship between pH, temperature, and rate of denaturation of wheat and soy proteins is complex. Optimum heat treatment of soy flakes, for example, inactivates nearly all the biologically active components, but the protein retains most of its functionality. Knowledge about protein denaturation helps to produce food products with desirable functional properties.

32. Ziemba, J. 1975. Food protein research accelerates -- a look at R&D and the future. Food Processing 36:8, 21-22.

Summary: The future of non-meat protein additives is discussed. Soybeans are predicted to continue as the main source of protein additives, with cereal grains like corn, wheat and oats also being used. Single cell proteins and leaf proteins will become increasingly important. The expense of protein isolates will limit their use. Safflower, cottonseed, and peanut proteins are other possibilities.

33. Can you beat the high cost of meat? 1973. Cooking for Profit. 42:5, 56.

Abstract: Ground beef, fish, and seafood prices are no longer within the "economy" range for protein sources. Substitutes worth considering are pollock, halibut, frozen fish, canned tuna, and salmon; textured vegetable proteins; dried peas, lentils, peanuts, and beans; cereals; eggs; and chicken (despite its increased price). An imaginative approach to the menu and a knowledge of the nutritive value of vegetable protein will help.

34. Progress on proteins. 1974. Institutions, Volume Feeding. 74:6, 33.

Abstract: Currently, the major source of vegetable protein in animal food analogs is soy protein. There is reason to believe that other vegetable or microbial sources of protein, such as wheat gluten and yeast, could also be used extensively. Products containing no cholesterol, lower quantities of fat, and about equal PER ratios are available now, and by 1980 it is expected that they will replace 10 to 20 percent of the meat items in the American diet. Soybean protein has more lysine than necessary for balanced protein nutrition and thus is an effective supplement for lysine-deficient cereals. The soybean is deficient in methionine and, in this case, cereals provide the complement. It is possible to define the parameters of soy products so that the shift from meat to soy does not diminish the nutrients

obtained from meat products. However, the problem of unknown micronutrients present in meat and not in soy and other vegetable protein products must be solved. The best defense against the unknown in nutrition is to strive for the greatest variety and diversity in foods. This also means broadening the base of raw materials in fabricated foods that serve as meat analogs.

35. Protein update - proteins by source, company and form. 1975. Food Processing 36:8, 26-27.

Summary: The source (corn, egg, meat by-products, peanut, wheat, yeast, soy, dairy, blends) of proteins with manufacturers and form (flour, powder, flakes, grits, granules, textured, miscellaneous) are listed.

36. Protein update, Guide to protein products and companies. 1975 Food Processing 36:8, 28-50.

Summary: A listing of 45 companies that produce protein products is given with brief descriptions of protein form, source, range, functional characteristics and applications.

37. More protein update 1975. Additional product and company information. Food Processing 36:11, 41-42.

Summary: A list is given of ten additional companies that produce protein products with information on their products. See Food Processing 36:8, 28-50 for original listing.

III. Soy Protein Extenders

Textured soy proteins have been used as extenders in institutional feeding for several years, but the use of soy proteins increased markedly in 1971 when the United States Department of Agriculture issued Notice 219 which permitted the use of 30% rehydrated textured vegetable products to replace up to 30% of the meat or meat alternate portion of the Class A school lunch menu. In 1973 the rapid increase in the price of ground meat spurred supermarkets to offer blends of ground beef and textured plant protein to consumers.

Although other plant proteins are receiving much attention in the literature, soy products still account for virtually all of the vegetable proteins used as extenders. The emphasis in research has been in improving processing procedures, achieving the most desirable functional properties, reducing the typical beany flavor of the soy products, establishing an acceptable level of use, and fortifying the soy products with additional amino acids to achieve a higher PER rating. The relative merits of using soy flour or grits, soy concentrates or soy isolates have also received much attention.

A. Soy Proteins; General

1. Alden, D.E. 1975. Soy Processing: from beans to ingredients. J. Am. Oil Chem. Soc. 52:4, 244A-248A

Abstract: Soybean processing does not end with the product's oil and meal. To the food ingredient business, this is only the beginning. This presentation is a simplified general scheme to show the processing of soybeans from the whole bean to each of its end protein ingredients and to show where they might fit into the food business. It portrays bean preparation and oil extraction, meal handling, and conversion of the meal into food ingredients. Soy flour, soy concentrates, soy isolates, and modified protein products, such as spun fibers and textured vegetable protein products, are covered. Some values and applications of the ingredients also are discussed.

2. Anton, J.J. 1975. Good market climate nurtures soy industry growth. Food Product Development 9:8, 96-99.

Summary: Three conditions are necessary for market success: (1) there must be a need to supplement presently acceptable products (2) substitutions must occur within the framework of existing products or promote acceptance of new products and (3) sufficient profit potential must exist to encourage the necessary research, production, and marketing effort. Tables are given on the yields of protein per acre (soybeans, other legumes, corn, wheat, milk, beef), the costs of various proteins (beef trimming, nonfat dry milk, sodium caseinate, soy flour, textured soy flour, soy concentrate, soy isolate), projected soy protein use in processed meats, market shift among soy ingredients, usage levels, and pricing of soy products.

3. Altschul, A.M. 1973. The revered legume, Nutrition Today, March/April, 22-29.

Summary: The history of the use of soybeans is discussed as well as the current usages, processing techniques, and nutritional values. Predictions are given for soy concentrate and spun protein use in processed, prepared and canned meat items in 1980. Total pounds of processed meat items is projected at 17,780,000,000 pounds in 1980 of which 10% to 21% may be replaced by soy protein.

4. Baldwin, A.R. 1974. Summary of the World Soy Protein Conference, J. Am. Oil Chemists' Soc. 51:1, 181A-184A.

Summary: A synopsis of the papers presented at the World Soy Protein Conference held in Munich, Germany November 11-14, 1973 is given. Eleven hundred delegates from 46 countries attended the conference.

5. Burket, R.E. 1974. Blending animal and vegetable proteins for today's market. Soybean Digest 34:2, 16.

Abstract: With the exception of such items as imitation bacon bits, dry convenience dinners, and products being sold as health foods, the bulk of edible soy proteins produced today are used as meat extenders in processed meats, such as patties, loaves, and sausages. These soy products, in addition to their protein contribution, provide structural integrity, binding, emulsifying, and fat absorption qualities. There is no better complement to such cuts as brisket, foreshank, flank, short plates, and organ meats and/or suet as the high-protein, low-fat soy protein products. Economics is another factor; soy grits cost about 15 cents per pound; textured soy proteins and soy protein concentrates about 30 cents; and isolated soy protein products about 60 cents. When hydrated with water to obtain the protein: moisture ratio of meat, the per-pound price ranges from 6 to 12 cents, in comparison with approximately $1 per pound for meat. The consumer shows a willingness to try meat-soy protein mixtures. The use of soy proteins in combination with meat will help keep processed meat products in a price range the consumer can afford.

6. Coppock, John. 1973. Soy proteins in foods - retrospect and prospect. J. Am. Oil Chem. Soc. 51:1, 59A-62A.

Abstract: The soybean has been used for food in the Orient for centuries, but the western world has been slow to adopt it. In the last 40 years soybeans have become an important source of protein in poultry and livestock feed. In the last 10 years or so it has been used in foods in increasing amounts to supply low cost high quality protein with important functional properties. The soybean will be vital to meeting the protein needs of the future in all parts of the world, especially in the developing countries. The challenge is great to the plant breeders and agronomists to improve yields and adaptability of the crop and to the soy technologists to improve the characteristics of processed soy bean proteins.

7. Czarnecki, J.N. 1974. Position of Soy Protein Processors in Relation to Laws and Regulations. J. Am. Oil Chem. Soc. 51:1, 110A.

Abstract: Soy protein products in the U.S. fall under the regulatory powers of the Food and Drug Administration as far as processing plants are concerned. The U.S. Department of Agriculture controls their use in meat and poultry products. Many states have separate regulations. The industry is expected to know federal and state regulations and interpret them for the customer. Difficulties arise for the processor when there are so many different state, Food and Drug Administration, U.S. Department of Agriculture, and foreign regulations that affect the products. This Conference (World Protein Conference, 1973) might spearhead world-wide cooperation in the development of future regulations.

8. Fischer, R.W. 1974. Future of soy protein foods in the marketplace. J. Am. Oil Chem. Soc. 51:1, 178A-180A.

Abstract: The food and commodity markets of 1973 signal a fundamental change in values of foods and agricultural products in relation to other goods and services. By 1985 non-traditional protein sources will be depended upon to supply a greater share of world demand for all proteins. By that time use of soy proteins for feeds and specialty foods can be expected to take 2 1/2-3% of an estimated world production of 81 million metric tons/year.

9. Horan, E. 1974. Soy protein products and their production. J. Am. Oil Chem. Society 51:1, 67A-73A.

Abstract: The soybean industry in the U.S. started in the first years of this century and was only 5,000,000 bushels just 50 years ago. In 1974 it is expected to be over 1.5 billion bushels, reflecting a remarkable growth. Beans are processed primarily for soybean oil and for meal to be used in poultry and livestock feeds. Only about 3% soy protein is used in human food today. Special processing is required to prepare proteins to meet the various specifications of products for the food industry. Methods used to produce flour and grits, spun fibers, textured proteins, concentrates and isolates are described.

10. Kellor, R.L. 1974. Defatted soy flour and grits. J. Am. Oil Chem. Soc. 51:1, 77A-80A.

Abstract: Defatted soy flour and grits are the most rudimentary forms of high protein products processed from the soybean, yet they are the soy products used in the largest volume by the food industry. To appreciate fully the contribution of defatted soy flour and grits to any food system, it is essential that a knowledge of the composition, nutritional value, and functionality of these products be well understood. Major emphasis is given to applications for defatted soy flour and grits with cereals.

11. Lockmiller, N.R. 1973. Increased utilization of protein in foods. Cereal Sci. Today 18:3, 77-81.

Summary: The general processing methods of soy products, their utilization and their nutritional value is presented. An 8% to 10% increase in soy protein utilization per year is predicted. Flow charts of the extrusion and spinning techniques are shown.

12. Mattil, K.F. 1974. Composition, nutritional and functional properties and quality criteria of soy protein concentrates and soy protein isolates. J. Am. Oil Chem. Soc. 51:1, 81A-84A.

Abstracts: The available commercial soy protein concentrates and soy protein isolates afford the food processor concentrated sources of protein with some interesting and varied functional properties. Each class of products is mild to bland in flavor and light in color. The concentrates contain at least 70% protein and the isolates 90%. The nutritional quality of the proteins is fair to good and can be excellent either by supplementation with 1.5% methionine or by appropriate blending with other sources of proteins. The concentrates provide the food manufacturer with products where a high protein content for unit of volume or weight is needed. The isolates are available for uses where the functional properties reside solely in the protein and the non-protein components may interfere. The adaptability of the proteins to modification by controlled processing conditions has made it possible for the manufacturers to produce a diversity of products that should be of interest to practically all food formulators.

13. Mussman, H.C. 1974. Regulations governing the use of soy protein in meat and poultry products in the U.S. J. Am. Oil Chem. Soc. 51:1, 104A-106A.

Abstract: There is much interest today in a greater use of vegetable protein in the human diet. Soy protein products currently are approved for use at low levels in over 30 different kinds of meat and poultry foods in the U.S. Recognizing a need for more flexibility in formulation of products under its jurisdiction, the Federal Meat and Poultry Inspection Program of the US Department of Agriculture has proposed several changes in its regulations. They variously define terms, describe types of vegetable protein products, and would permit use of such products in many meat and poultry foods provided the labeling was descriptive and adequately reflected their presence. In addition, the program would require compliance with nutritional equivalency parameters where vegetable protein was substituted for animal protein in traditional meat or poultry foods. Comments received from the regulated industry and the consuming public on these proposals are being reviewed and evaluated to develop a set of final regulations. Though they will result from the best information available these regulations still will be subject to change as new data are developed. Because combinations of animal protein and vegetable protein appear to be taking on greater importance for the future, the U.S. Department of Agriculture's Meat and Poultry Inspection Program will work with the meat industry, various segments of the agricultural community, and other interested groups to encourage greater innovation in the use of total protein resources.

14. Rakosky, J. 1975. Soy protein in foods: their use and regulations in the U.S. J. Am. Oil Chem. Soc. 52:4, 272A-275A.

Abstract: Soy proteins have been used at an ever increasing rate in various food systems because of their beneficial functional properties and low costs. Their use has been limited because of taste, regulatory restrictions, and prejudice on the part of many. As technology advanced and as consumer needs changed, these limiting factors became less of a restriction. Flavor and functionability were improved through the introduction of new products or altered processing. The greatest change in regulatory attitude did not come about until after the White House Conference on Nutrition, when it was recommended that the consumer be given the advantages found in the new technologies that were being advanced. In making these changes, a number of new problems have been encountered. These problems, as well as the apparent trend in regulatory action, are discussed.

15. Watanabe, T. 1974. Government role and participation in development and marketing of soy protein foods. J. Am. Oil Chem. Soc. 51:1, 111A-115A.

Abstract: Japan has a history of utilizing soybeans as human foods. Currently, a great quantity of defatted soybeans is used as animal feed in Japan, and governmental and commercial enterprises are anxious to turn the defatted soybeans directly into foods for humans. Therefore, they are putting great efforts into soybean research and development. Since the demands for better foods are rising and their resources are not abundant, the author feels that soybean protein will play an important role by exerting its unique properties, not only to supplement other foods, but also to grow into new types of foods when their unknown properties are disclosed.

16. Watson, J. 1974. New protein food. Nutrition 28:4, 249.

Abstract: The manufacture, nutritional value, acceptability, and uses of textured soy protein are described.

17. Wilcke, H.L. 1974. Future developments in soy protein research and technology. J. Am. Oil Chem. Soc. 51:1, 175A-177A.

Abstract: The many successful and desirable uses of soy products were recounted in the talks at the World Soybean Conference (1973). The following were emphasized: that practically every natural food can be improved in its adaptation to food for man. This includes milk. Improvement may be made by deleting certain undesirable factors such as flavors, odor, or anti-nutritional factors. Many of these undesirable factors have been recognized and either eliminated or reduced to insignificance. Further improvement may be made by enhancing functional and nutritional characteristics. Acceptance of soybean products as desired food constituents can result in further improvement in both yield and quality of the basic product as well as of the flours, concentrates, and isolates, which in turn may result in more economical production and processing costs. The best progress is accomplished

by those who recognize the inherent problems in the products and who are honestly willing to do something about them. It is the responsibility of every processor of food products, in the U.S. and elsewhere, to produce food products worthy of the quality of the raw product from which they are produced. This is particularly true of soybeans. The observance of all these factors will result in a real contribution to the food industry throughout the world.

18. Wodicka, V.O. 1974. Authorizations and restrictions on soy protein in foods in the U.S. J. Am. Oil Chem. Soc. 51:1, 101A-103A.

Abstract: The Food and Drug Administration makes the basic decisions on what materials will be permitted in U.S. foods. The U.S. Department of Agriculture then selects those items which it will allow in meats and poultry products. The Food and Drug Administration is in the process of developing definitions for soy products and issuing the regulatory controls over their uses. Care is being taken not to impose burdensome regulatory restrictions on a technology that is in a rapid state of development.

19. Wolf, W.J. 1972. What is soy protein? Food Technol. 26:5, 44-54.

Summary: A general explanation of the physical and chemical characteristics of protein is given including the cellular structure, common forms, amino acid composition, protein classification, protein solubility, solubility of isolates, molecular size distribution, gel electrophoretic behavior, association-dissociation reactions, sub-unit structure, effects of heat, and denaturation studies.

20. Wolf, W.J. 1974. Soybean proteins: Their production, properties and food uses. A Selected Bibliography J. Am. Oil Chem. Soc. 51:1, 63A-66A.

Abstract: Key references have been selected to provide an introduction to production, properties, and food uses of soybean proteins.

21. Soy protein fiber...costs 45% less than spun. 1972. Food Processing 33:4, F4.

Summary: Structured soy protein fiber, manufactured from soy isolates offers a relatively inexpensive means of extending meat items. They can be retorted for extended periods, and used as a binder in natural products lacking suitable textur

22. The super soybean: protein potential, prospects and products. What's New in Home Economics. 1974. Vol 38:6, 18.

Abstract: Soy proteins are present in many forms and flavors, including grits and flours, concentrates and isolates. Soy protein products for home use are primarily meat extenders and analogs. Photographs of analogs are included along with storage and use tips.

B. Soy proteins; Processing techniques and their effect on physical, chemical, and functional properties.

1. Aguilera, J.M. and Kosikowski, F.V. 1976. Soybean extruded product: A response surface analysis. J. Food Sci. 41:3, 647-651.

Abstract: Response Surface Analysis (RSA) was used to study the effect of three variables, process temperature (120,145 and 170°C), feed moisture content (20, 30 and 40%), and screw speed (800, 900 and 1000 rpm) on extrudate characteristics. Unheated soybean flakes extruded under different conditions were subjected to Warner-Bratzler shear (WBS), water absorption (WA) measurements and residual trypsin inhibitor activity (TIA) assays. Low feed moisture contents induced higher internal heat production causing residual TIA in the product to be lower than expected, WA to increase, and WBS to be independent of process temperature at constant screw speed of 900 rpm. Variation of screw speed permitted the attainment of desired values of product characteristics when moisture and temperature had to be fixed.

Response surface analysis (RSA) is based on the assumption that when K factors (or independent variables) are being studied in an experiment, the response (or dependent variable) will be a function of the levels at which these factors are combined ($\underline{Z}/_K$) Thus $Y = \phi \quad (\underline{Z}/_1, \underline{Z}/_2 \quad \underline{Z}/^k)$ (y = response function). See Ladmor and Klein, 1970, Engineering Principles of Plasticaling Extrusion, p. 450 Van Nostrand Reinbold Co., N.Y. for additional explanation of RSA.

2. Anderson, R.L., Wolf, W.J. and Glover, D. 1973. Extraction of soybean meat proteins with salt solution at pH 4.5 J. Agric. Food Chem. 21:2, 251-254.

Abstract: Extractable Kjeldahl nitrogen increased with increases in concentration of sodium or calcium chloride until a maximum of 65% of the nitrogen in the flakes was extracted. This maximum occurred with 0.3 N calcium chloride or 0.7 N sodium chloride. Without added salts, the pH 4.5 extract contained only 2S and 7S ultracentrifuge components. Up to 0.3 N sodium chloride 2S protein increased, whereas the 7S component did not reach a maximum until 0.7-0.8 N salt. The 11S component began to dissolve at 0.3 N salt and was completely solubilized at 0.8N. The 15S component did not dissolve until concentrations of salt were greater than 0.4 N and increased in extractability up to 0.8 N sodium chloride. Calcium chloride extracts contained increasing amounts of 2S and 7S fractions up to 0.2 and 0.3 N, respectively. The 11S component began to dissolve at 0.1 N and increased in solubility up to 0.4 N calcium chloride. The 15S material did not dissolve significantly below 0.2 N and increased in extractability up to 0.4 N calcium chloride.

3. Cumming, D.B., Stanley, D.W., and De Man, J.M. 1973. Fate of water soluble soy protein during thermoplastic extrusion. J. Food Sci. 38:2, 320-323.

Abstract: Polyacrylamide disc gel electrophoresis was employed to evaluate the changes in water soluble soy protein resulting from thermoplastic extrusion. As temperature increased and other processing parameters were held constant the general electrophoresis pattern was altered considerably and much of the protein became insoluble. Six major fractions were designated and tentatively identified. As a result of processing, the intact soy proteins yielded breakdown products consisting of multiples of a 28,000 MW (molecular weight) subunit. For good texturization it is apparently necessary that a significant proportion of the water soluble protein becomes insoluble as a result of thermal processing.

4. Hermansson, A.M. 1975. Functional properties of added proteins correlated with properties of meat systems. Effect on texture of a meat product. J. Food Sci. 40:3, 611-614.

Abstract: Texture changes observed when 4% proteins were added to a commercial meatball recipe correlated with changes in the functional properties of the added proteins. Proteins added were untreated soy protein isolate, caseinate and whey protein concentrate, preheat-treated soy protein isolate and whey protein concentrate. Good statistical correlations were found between texture changes of meatballs and moisture loss changes of model meat systems. When regression equations calculated from moisture loss studies were used on the texture changes of meatballs, correlation coefficients as high as 0.88 were obtained. Of the functional properties, swelling and gel strength were shown to be of great importance for the texture changes of meatballs.

5. Hermansson, A.M., and Akesson, C. 1975. Functional properties of added proteins correlated with properties of meat systems. Effect of concentration and temperature on water-binding properties of model meat systems. J. Food Sci. 40:3, 595-602.

Abstract: The effects of some functional properties (e.g., solubility, viscosity, swelling and gel strength) of added proteins on moisture loss properties of model meat systems were studied. The protein preparations, soy protein isolate (Promine-D), caseinate and whey protein concentrate were added to pork shoulder and beef brisket systems, and changes were observed with respect to temperature and percent exchanged protein. Observed changes in moisture loss properties were correlated with the corresponding changes in functional properties by certain regression procedures. The best statistical solution from changes on raw meat systems had a correlation coefficient of 0.99, with solubility explaining 79%, swelling 10% and viscosity 10% of the variance. The best statistical solution for heat-treated systems had a correlation coefficient of 0.98, with gel strength alone explaining 94% of the variance.

6. Hermansson, A.M. and Akesson, C. 1975. Functional properties of added proteins correlated with properties of meat systems. Effect of salt on water-binding properties of model meat systems. J. Food Sci. 40:3, 603-610.

Abstract: The effects of solubility, swelling, viscosity and gel strength properties of added proteins on moisture loss properties of raw and heat-treated model meat systems with varying salt content were studied. Proteins added were soy protein isolate (Promine-D), caseinate and whey protein concentrate. Quantitative interrelationships of functional properties were calculated by a general metric hierarchical clustering technique, and correlations between functional properties and moisture loss properties by multiple regression analysis. In addition, penetration studies were made. The addition of salt decreased the moisture loss of all the meat systems tested. The functional properties of the added protein were, however, very differently affected by the addition of salt. Although complex behavior occurred due to salt addition, good statistical correlations were obtained between differences in functional properties and differences in moisture loss properties. The best statistical solutions on raw and heat-treated meat systems had correlation coefficients of 0.82 and 0.98, respectively.

7. Lauck, R.M. 1975. The functionality of binders in meat emulsions. J. Food Sci. 40:4, 736-740.

Abstract: The functionality of commercially available sausage binders, containing significant amounts of protein as partial replacements for meat in imitation frankfurters, was investigated. Meat emulsions were formulated for least-cost with a linear program. The meat emulsions were prepared in the laboratory by chopping meat and other ingredients in a metal Omni-Mixer cup which was cooled in ice water. A sample of the emulsion was cooked to 79°C and the free water and fat expressed into a volumetric cylinder for a measure of emulsion stability. The binders which were studied included partially delactosed whey, whey protein concentrate, dried sweet whey, "lactalbumin," nonfat dried milk and soy isolate. Optimum finished emulsion temperature for the all-meat frankfurters was about 14°C although ENR-EX, a binder derived from partially delactosed whey, performed best at 20°-25°C. Pilot plant studies indicated that only ENR-EX successfully replaced some of the beef in an all-meat frankfurter control formula. Meat emulsions prepared and cooked in the laboratory were much more predictive of results in the pilot plant than were model systems which involved titration of protein dispersions with liquid fat.

8. Milligan, E.D. and Suriano, J.F. 1974. System for production of high and low protein dispersibility index edible extracted soybean flakes. J. Am. Oil Chem. Soc. 51:4, 158-161.

Abstract: A standard flash desolventizing system has been combined with horizontal agitated meal stripping and cooking vessels operating at atmospheric pressure to provide an integrated system for the production of high, intermediate, or

low protein dispersability index edible soybean flakes from extracted solvent-wet flakes. Flash desolventizing removes most of the hexane in the wet flakes by evaporation at low temperature in a turbulent stream of superheated hexane vapor. The small remaining hexane quantity is removed in a stripping process capable of producing the full range of protein dispersability index values in the flakes by treating the flash desolventized flakes with either dry superheated steam or wet saturated steam under carefully controlled conditions of steam temperature, pressure, flow rate, and moisture content. The products are light colored, with little production of fine particles.

9. Puski, G. 1975. Modification of functional properties of soy proteins by proteolytic enzyme treatment. Cereal Chem. 52:5, 655-664.

Abstract: Soy protein isolate was treated with various amounts of neutral protease preparation from *Aspergillus oryzae*. The extent of enzyme treatment was determined by measuring the increase in free amino groups. The functional properties of these enzyme-treated soy isolates and untreated controls were examined. As expected, soluble nitrogen was increased, both at neutral pH and at the isoelectric point, and in the presence of 0.03M calcium chloride, with increased enzyme treatment. Even limited enzyme treatment significantly reduced the viscosity of concentrated protein solutions and prevented gel formation. Emulsification capacities as measured by a modified Swift et al. method, were increased with enzyme treatment (ref this document), but emulsion stabilities were decreased. The enzyme-treated proteins had slightly increased water absorption and foaming properties, but foam stability was very low.

10. Rackis, J.J., McGhee, J.E. and Honig, D.H. 1975. Processing soybeans into foods: Selected aspects of nutrition and flavor. J. Am. Oil Chem. Soc. 52:4, 249A-253A.

Abstract: Since many new soy protein products are being developed which differ in enzyme activity, protein dispersibility, flavor, nutritive value, and functional properties, quality control is assuming increasing significance. The effects of dry and moist heat and hexane:ethanol azeotrope extraction upon various enzymatic activities, protein solubility, and nutritive value of defatted soy flakes differ considerably. Specifications and guidelines initially developed to establish the degree of moist heat treatment required to produce edible grade products need to be reevaluated for these processes. Flavor scores of hexane:ethanol azeotrope-extracted flakes and proteinates prepared from them are significantly higher than those prepared by current commercial practices. Because peroxidase is a much more stable enzyme than lipoxygenase, determination of peroxidase activity may be a more suitable method to define proper processing conditions which improve the flavor of soy products. A combination of hexane:ethanol extraction and steaming improves the flavor and nutritive

value of defatted soy flakes. Azeotrope extraction alone does not inactivate trypsin inhibitors; nutritive value of the extracted flakes is low, and pancreatic hypertrophy occurs when they are fed to rats. Protein efficiency ratio of the processed flakes is 2.2 on a basis of a value = 2.5 for casein. Other factors to be considered to prepare soy protein isolates of good nutritional quality are: choline deficiency, variability in sulfur amino acid content, and formation of phytate complexes that affect bioavailability of essential minerals, particularly zinc.

11. Rosenfield, D. and Hartman, W.E. 1974. Spun-fiber textured products. J. Am. Oil Chem. Soc. 51:1, 91A-94A.

Abstract: The process for spinning fibers from soy isolate is described. Fabrication of so-called food analogs and extenders containing spun soy fibers is reviewed. The rationale for the use of fibers in food products and ingredients is explored. Nutritional properties, especially protein quality, of the products are discussed. Emphasis is given to the fact that spun-fiber textured products contain a variety of items, such as soy, wheat, oats, egg albumen, yeast, sodium caseinate, and vegetable oils. The relationship of this variety to applied nutrition is discussed.

12. Saio, K., Terashima, M. and Watanabe, T. 1975. Food use of soybean 7S and 11S. Changes in basic groups of soybean protein by high temperature heating. J. Food Sci. 40:3, pp 541-544.

Abstract: Protein paste of 25% concentration from cold insoluble fraction (CIF) or crude 7S was autoclaved at 100-170°C to prepare heat-induced gel. After solubilization of gel, quantitative changes in Amido Black 10B bound to protein, basic amino acids and amide groups during heating, were investigated. In these experimental conditions, no significant change in basic amino acids were recognized but decreases of amide groups and the amount of Amido Black 10B bound were significant as temperature of heating increased. The decrease began from 105°C in CIF-gel and from 140°C in crude 7S-gel. From the results on Amido Black 10B bound to protein and on SDS-disc polyacrylamide gel electrophoresis, the gross structure of subunits derived from gel was degraded into lower molecular substances by heating at above 150°C. The relationship of these results with those of our previous reports on gel properties, solubility and others are also discussed.

13. Saio, K., Terashima, M. and Watanabe, T. 1975. Food use of soybean 7S and 11S Proteins. Heat denaturation of soybean proteins at high temperature. J. Food Sci. 40:3, pp 537-540.

Abstract: Qualitative changes in 7S and 11S proteins during heat treatment at 100-170°C were studied. Protein paste of 25% concentration was autoclaved and the resultant heat-induced gel was submitted to measurement of its solubility,

ultra-centrifugal characteristics and disc polyacrylamide gel electrophoresis after disolving with sodium dodecyl sulfate and 2-mercaptoethanol. The results showed: (1) heating over 100°C resulted in the formation of an insoluble gel; (2) during heating up to 140°C the gel gradually became soluble but the gross-structure of subunits remained unchanged, 11S-gel being more soluble than 7S-gel even at lower temperature; and (3) during heating at above 150°C, the gel became highly soluble, showing degradation of the gross-structure of subunits.

14. Saio, K., Watanabe, T. and Kaji, M. 1973. Food use of soybean 7S and 11S proteins. 1. Extraction and functional properties of their fractions. J. Food Sci. 38:7, 1139-1144.

Abstract: Calcium precipitation behavior of soybean 7S and 11S proteins are described and discussed. Results suggest that 11S protein precipitates more rapidly with less calcium than 7S protein. Based on the difference of precipitation behavior between the two proteins, the paper proposes a practical method to fractionate 7S and 11S protein rich fractions (7S PRF and 11S PRF), using a direct extraction from defatted meal with a dilute calcium chloride solution. The ratio of 11S to 7S in 11S PRF is 3:1 and that in 7S 1:4. Functional properties of the fractions were investigated, with prepared calcium gel, heat-induced gel, cheese-like food, kamahoko-like food (fish paste product) and a sausage-like food. Preliminary results attest existence of a remarkable difference between 7S PRF and 11S PRF.

15. Saio, K., Sato, I. and Watanabe, T. 1974. Food use of soybean 7S and 11S proteins. High temperature expansion characteristics of gels. J. Food Sci. 39:4, 777-782.

Abstract: High temperature expansion characteristics of soybean gels coagulated with calcium salt or HCl were studied. Results show (1) that the high ionic strength and slight alkaline or acidic range of buffer in which the gels were immersed, promoted expansion characteristics of gels; (2) the higher ratio of 11S to 7S protein in the gels resulted in higher expansion; and (3) presence of sodium sulfite prevented gels from expansion. The binding forces attributed to construct gels before and after expansion are discussed based on studies of expansion characteristics of gels in different conditions and on solubility of gels with 2-mercaptoethanol and sodium dodecyl sulfate.

16. Van Megan, W.H. 1974. Solubility behavior of soybean globulins as a function of pH and ionic strength. J. Agric. Food Chem. 22:1, 126-129.

Abstract: The solubility behavior of partially purified soybean globulins as a function of pH and ionic strength of the dispersing medium was investigated. It appeared that, even at the isoelectric point, the soy protein could be dissolved easily up to very high concentrations, provided that the ionic

strength of the solution exceeded a critical value which, at pH 4.5, was about 0.7 for NaCl and Na_2SO_4 and 0.25 for $CaCl_2$. Below the critical ionic strength a two-phase system was formed, consisting of a protein-poor upper layer and a viscous protein-rich lower layer. At pH 7.0 no phase separation was observed at very low ionic strength but, as the salt concentration was increased, a region was passed in which the solution demixed. Outside the regions of immiscibility only homogeneous systems were obtained. The composition of the protein-poor layers in the two-phase systems was in agreement with the well known protein extractability curves for soybean meal.

17. Wang, L.C. 1975. Ultrasonic extraction of proteins from autoclaved soybean flakes. J. Food Sci. 40:3, pp 549-551.

Abstract: Amounts of proteins extracted from soybean flakes by applying ultrasonic waves and by conventional stirring were compared. Respective yields of the total proteins from unautoclaved and autoclaved flakes were 60% and 16% by conventional stirring and 88% and 58% by sonication in a single 1:10 meal-to-water extraction. From autoclaved flakes, sonication in a single extraction dispersed up to 78% total proteins in water with 1:40 meal-to-water ratio. Sonication recovered a portion of proteins from autoclaved flakes ordinarily unattainable by conventional stirring extraction. Proteins obtained by either method revealed no differences in their ultracentrifuge patterns.

18. Wolf, W.J. 1970 Soybean proteins. Their functional, chemical and physical properties. Agric. and Food Chem. 18:6, 969.

Abstract: Soybean proteins are available to the food industry in the form of flours and grits, concentrates, and isolates with respective protein contents of 40-50%, 70%, and 90% or more. These proteins, when added to a variety of foods, supply desirable functional properties, such as emulsification, fat absorption, moisture holding, thickening, and foaming. Soybean proteins are mainly globulins with minimum solubilities near pH 4.5, and consist of a mixture of components with molecular weights ranging from 8000 to 600,000. Two of the major components, the 7S and 11S globulins, form insoluble disulfide polymers, undergo association-dissociation reactions, and have quaternary structures. The quaternary structures are disrupted by acids, alkalis, urea, detergents, and heat. Concentrated solutions of protein isolates increase in viscosity and gel when heated. Heating dilute solutions of 11S globulin causes about one-half of the protein to precipitate, while the other half is converted into a 3-4S form that remains soluble.

C. Soy proteins: source, elimination and addition of flavors

1. Anderson, R. L. and Warner, K. Acid sensitive soy proteins affect flavor. 1976 J. Food Sci. 41:2, 293-296.

Abstract: The acid-sensitive fraction (ASF) is easily removed from other soy proteins because it precipitates from 1 M NaCl at pH 4.5. This precipitation provides the basis for an ASF assay. An ASF containing sample series was compared by disc gel electrophoresis with an analogous series after ASF elimination. These two series were also evaluated by a trained 12-member taste panel. Six prominent and several minor proteins throughout the gels and unresolved protein near the top of the gels appear to be associated with ASF. Disc gel electrophoresis reveals that the water-extractable proteins, the acid-precipitated curd and the whey proteins contain ASF. Its removal significantly increased flavor scores; the most noticeable change is a decrease in the intensity of grassy-beany flavor. Evidently ASF has a greater affinity for grassy-beany flavor compounds than do non-ASF proteins.

2. Eriksen, S., and Fagerson, I.S. 1976. The plastein reaction and its application: A review. J. Food Sci. 41:3, 490-493.

Abstract: Various methods for removing the bitterness arising from enzymatic hydrolysis of soybean and casein are reviewed. The plastein reaction is discussed in detail as well as its use in incorporating essential amino acids into the structure of soy protein plastein. Practical use of the B/a parameter in controlling the plastein reaction and in trying to enhance plastein productivity is reviewed along with alternate theories for plastein formation. Concludes that the plastein reaction has great potential (from a food processing point of view) provided the process can be controlled on an industrial scale; however, more intensive theoretical and practical investigations are needed before commercial utilization will be successful.

3. Fischetti, F. 1975. Flavoring textured soy proteins. Food Product Development 9:6, 64.

Summary: Flavors may be added prior to extrusion, after extrusion or both. Either water or oil soluble flavorings can be used. Best results are usually obtained with oil soluble flavorings added after extrusion. The textured soy concentrates and isolates interact to bind flavorings. A problem arises because soy is somewhat selective, binding certain functional groups and not others. Heating also causes changes which must be taken into consideration.

4. Goosens, A.E. 1974. Protein foods - flavors and off-flavors. Food Engineering 46:10, 59.

Abstract: Protein foods are a challenge to the creative flavorist. He must consider the off-flavors in the raw materials, those which may be developed in processing, plus those imparted by added flavors and by flavor decomposition. To develop a flavor for a vegetable protein food that imparts a flavor profile

equal to its natural counterpart, he must tailor-make the flavor for each application. Off-flavors in soybeans are classified by functional groups (alcohols, aldehydes, ketones, phenols, amines, esters, acids, and sulfides). The raw materials being used in the U.S. to make meat flavorings are listed.

5. Gremili, H. A. 1974. Interaction of flavor compounds with soy proteins. J. Am. Oil. Chem. 51:1, 95A-97A.

Abstract: The addition of flavors to soy protein products often results in a loss or change of the flavor. Processing parameters and especially the specific sorption properties of soy protein for many organic compounds strongly influence the flavor performance in such products. A systematic study on the interactions of individual classes of flavor compounds (alcohols, carbonyls, etc.) has been conducted. In this paper methods used, the results obtained and the practical consequences for flavoring soy products are presented. The discussion also includes the influence of processing conditions during texturization of soy protein on the flavor.

6. Gruell, E.H.M. 1974. Some aspects of research in the application of soy proteins in foods.J. Am Oil Chemists Soc. 51:1, 98A-100A.

Summary: Two off-flavor precursors have been identified and a new method of concentrating soy has been developed. The two off-flavor compounds were identified as 4 vinyl phenol and 4 vinyl guaiaco. The precursors were the corresponding cinnamic acids which decarboxylate upon heating. Both precursors can be extracted from soy meats with polar solvents.

7. Honig, D.H., Warner K., and Rackis, J.J. 1976. Toasting and hexane: ethanol extraction of defatted soy flakes, flavor of flours, concentrates and isolates. J. Food Science 4:3, 642-646.

Abstract: "Flours and protein concentrates, prepared from defatted soybean flakes steamed up to 20 min before or after extraction with hexane: ethanol azeotrope 82/18 v/v, were presented to a 15-member trained taste panel. Flavors and odors were described and rated for intensity on a scale of 1 to 10 where 1 is strong and 10 is bland. Azeotropic extraction for 6 hours by itself significantly affected flavor of flours and of concentrates so that they scored 7.4 and 6.8, respectively, compared to 4.0 for raw, hexane-defatted, soy flour. Toasting after azeotropic extraction raised flavor scores of flours and protein concentrates to 7.9, a value which compares flavorably with 8.1 for wheat flour. Toasting is also necessary to inactivate trypsin inhibitors and other antinutritional factors in azeotropic-extracted soybean flakes. A protein isolate from toasted, azeotropic-extracted flakes scored 7.3 compared to 8.0 for sodium caseinate. Yields of protein isolates are good if the heat-processed flakes are extracted with hot water at 74°C and pH 7.2."

8. Maga, J.A. 1973. A review of flavor investigations associated with the soy products, raw soybeans, defatted flakes and flours, and isolates. J. Agric. Food Chem 21:5, 864-868.

Abstract: Soy products such as those mentioned in the title represent excellent protein sources and are readily available. However, one of the primary limitations on their more widespread use is the objectionable flavor normally associated with these products. This review brings together some of the more pertinent published reports on the flavor aspects of the above soy products to provide a historical review of what has been done and also stimulate additional research in other soy flavor related areas in order that soy flavor can be more fully understood and appreciated.

9. Rackis, J.J., Honig, D.H. and Sessa, D.J. 1972. Lipoxygenase and peroxidase activities of soybeans as related to the flavor profile during maturation. Cereal Chem. 49:5, 586-597.

Abstract: Based on these studies of maturing soybeans, it is concluded that beany and bitter constituents preeist in immature soybeans. Beany, bitter, and other objectionable flavors are also formed under certain processing conditions, such as in wet grinding and blending of raw full-fat soybeans. As a result, development of processes for the preparation of bland soy-protein products needs to take into account two factors: (a) effective removal of preexisting flavors, and (b) prevention of removal, or both, of derived flavor constituents. Hawkeye and Amsoy soybeans were picked at 15 intervals from 24 to about 66 days after flowering. During maturation, percentage of dry matter increased from 16 to 92 and total dry matter from 5 to 243 mg. per bean. Flavor intensities of each picking were determined by a taste panel. Lipoxygenase activity of beans of similar fresh weight, picked on the same day, was measured by the oxygen uptake method. Beany and bitter were the two predominant flavors in maturing soybeans. Most tasters used the terms green-beany, beany, and raw beany to describe the "beaniness" of soybeans. Grassy was an infrequent response. Beany and bitter flavor responses were recorded as flavor intensity values (FIV) based on a scale of 1 for weak, 2 for moderate, and 3 for strong. FIV with respect to beany varied from 2.0 to 2.7 during maturation, with the average being 2.4; no significant trends were noted. The average FIV for bitter for the two varieties increased threefold from about 0.54 in immature soybeans to 1.9 at maturity. Lipoxygenase activity at pH 6.8 varied from a low of 12 micrometers O_2 per min. per mg. dry matter in the early stages to 35 at 34 days after flowering, then down to 23 at 45 days, up to 43 at about one week before maturity, and them slowly decreased to about 32 microliters O_2 uptake at maturity; O_2 uptake values of 11 to 23 microliters were recorded for lipoxygenase activity; at pH 9.0. The FIV for beany did not correlate with changed in lipoxygenase activity; however, a correlation ($r = 0.73$) exists between lipoxygenase activity and the increase in FIV for bitter flavor as beans mature. An active peroxidase capable of utilizing linolenic hydroperoxide was also present. Peroxidase activity remained relatively constant throughout most of the maturation period, except for a large decrease at maturity.

10. Sessa, F.J., Warner, K. and Honig, D.H. 1974. Soybean phosp atidylcholine develops bitter taste on autoxidation. J. Food Sci. 39:1, 69-72.

Abstract: Soybean phosphatidylcholine (SPC) and hydrogenated SPC were isolated by column chromatography from commercial lecithin and hydrogenated lecithin, respectively. Aqueous suspensions of these preparations with added Cu^{++} were stored at 25°C. A seven-member taste panel rated dilutions containing 0.1% phospholipid for intensity of bitterness, based on the scoring system: 0 = none to 3 = strong. Both SPC and hydrogenated SPC initally rated a score of 0.8. A score of 1.6 was given when a suspension of SPC exhibited maximum absorbance due to diene conjugation. The score increased to 3.0 after 4 wk of storage. The development of bitter taste appeared to be associated with extent of oxidation of SPC as determined by thiobarbituric acid assay. Since no changes in taste occurred with hydrogenated SPC treated similarly, bitterness development is attributed to autoxidation of the constituent unsaturated fatty acids.

11. Wang, L.C. Warner, K., Wolf, W.J. and Kwolek, F. 1975. Apparent odor threholds of polyamines in water and 2% soybean flour dispersions. J. Food Sci. 40:2, 274-276.

Abstract: Apparent odor thresholds of putrescine, cadaverine, spermidine and spermine were determined in water and in 2% soybean flour dispersions. In neutral aqueous solutions respective apparent odor thresholds for putrescine, spermine, spermidine and cadaverine were 22, 24, 129 and 190 ppm. In 2% soybean flour dispersions, the odor threholds of putrescine and spermidine increased five to tenfold; evidently, soybean flour masks odors of the polyamines. Because polyamines are present in soybeans at levels lower than thresholds, their contribution of characteristics amine odor to soybean products may be negligible.

12. Wolf, W.J. 1975. Lipoxygenase and flavor of soybean protein products. J. Agric. and Food Chem. 23:2, 136-141.

Abstract: Work of the last 10 years indicates that lipids are a major source of compounds responsible for objectionable flavors in soybean protein products. Lipoxygenase is an important factor in the generation of flavor compounds from the lipids when soybeans are processed under high moisture conditions as in the preparation of soy milk by the traditional process. Less certain in the significance of lipoxygenase action when soybeans are processed under low moisture conditions as in the commercial extraction of oil. However, the potency of the flavor compounds that can arise by decomposition of hydroperoxides generated by lipoxygenase suggested that very little oxidation may be needed to give rise to objectionable levels of flavor constituents. Consequently, lipoxygenase cannot be ruled out as a causative factor until further work clearly demonstrates that lipoxygenase catalysis is not occurring at low moisture levels. High temperature is the key step currently proposed for inactivation of lipoxygenase during processing of soybeans. Options available are: (a) grinding with hot water; (b) dry heating-extrusion cooking; (c) blanching; and (d) grinding at

low pH followed by cooking. Products from such processes have improved flavor, but may lack functionally because of poor protein solubility caused by heat treatment. An alternative approach is to extract the flavor components after they are formed with hexane-ethanol or hexane-2-propanol. Relatively little denaturation of the proteins occurs with these extraction solvents.

13. 'Good tasting' soy products. Food Processing, 33:6, 1972, F7.

Summary: Deactivation of enzyme is the key to preventing the "painty" or "beany" flavor associated with soybean flavors. Numerous methods of enzyme deactivation are satisfactory; however, the timing is essential. The unwanted flavor develops under two conditions - - cracking of the bean and high moisture.

14. Inexpensive soy flours now offer good flavor. 1975. Food Processing 35:7, 40.

Summary. Full-fat and low-fat soy flours are now becoming available. Unlike defatted flours, they are free from the "beany" flavors. The flours are processed from soybeans that are cooked before the cracking, dehulling and grinding process. The heat treatment is the key factor in retarding the development of undesirable flavors and enhancing shelf life.

D. Soy proteins: nutritional aspects

1. Baker, E.C. and Mustakas, G.C. 1973. Heat Inactivation of trypsin inhibitor, lipoxygenase and urease in soybeans: effect of acid and base additives. J. Am. Oil Chem. Soc. 50:5, 137-141.

Abstract: Effects of chemical additives on the heat inactivation of trypsin inhibitor (TI), lipoxygenase and urease in soybeans were investigated. The nutritional value of soybeans increases when antigrowth factors, such as TI, are inactivated. Inactivation of lipoxygenase enhances palatability and storage stability. Heat inactivation of antinutritional factors during immersion cooking of dry soymeats was studied without additives. Processing time was varied from 15 min to 2 hr over a temperature range of 120-212° F. The experiments were repeated, with the addition of NaOH or HCl to the cooking water. Without additives, lipoxygenase proved to be the most heat labile and TI, the least. With either acid or base additives, the initial inactivation of urease and lipoxygenase was accelerated significantly; however, while TI inactivation was accelerated by base, it was retarded by acid addition.

2. Balla, F. 1974. Nutritive value and economic aspects of fortification of foods of plant origin with soy protein. J. Am Chem. Soc. 51:1, 156A-160A.

Abstract: The protein requirements of children and adults are reviewed in comparison with the protein qualities of several foods with and without added soy. The economic considerations greatly favor soy containing foods for equivalent nutrition.

3. Bookwalter, G.N., Warner, K., Anderson, R.A., Mustakas, G.C., and Griffin, E.L., Jr., 1975. Fortification of dry soybean based foods with DL-methionine. J. Food Sci., 40:2, 266-270.

Abstract: The addition of small amounts of DL-methionine enhanced the nutritional value of soy foods as determined by protein efficiency ratios. Regular CSM (corn soy milk), instant CSM, both unsweetened and sweetened soy beverage base and full-fat soy flour were formulated to contain up to 106 mg DL-methionine per gram nitrogen. The products were stored at 25, 37 and 49°C for up to 12 months. Fortified full-fat soy flour received slightly lower flavor scores than its unfortified control after storage for 2 months at 49°C and for 6 months at 37°C. Fortified soy beverage base received lower flavor scores than its unfortified control in some tests, but differences were slight. Although slight flavor differences occurred during storage of fortified formulations containing soy protein, all flavor scores were satisfactory. As indicated by peroxide values and levels of free fatty acids, fat stability was unaffected by the presence of DL-methionine. Retention of DL-methionine was also satisfactory under the test conditions.

4. Bressani, R. 1975. Nutritional contribution of soy protein to food systems. J. Am. Oil Chem. Soc. 52:4, 254A-262A.

Abstract: From the nutritional point of view, soybeans can play a significant role in at least three aspects: as a source of supplementary and complementary protein, as a source of calories, and as a source of nitrogen. The protein role is probably the most important for food systems of developed and underdeveloped populations, while the role as a source of protein and calories applies more to food systems of developing populations. Soy protein efficiently supplements cereal grain protein, because it corrects the lysine deficiency of cereals. In some cases, for example with maize, it also corrects the tryptophane deficiency. On the other hand, the essential amino acid pattern of soybean protein complements that of other protein sources, for example cereal grains, cottonseed flour, and, in general, lysine deficient protein sources. This makes feasible the preparation of foods of optimum protein quality and of a high protein content. Because of its quality, soybean protein can replace animal protein without a significant decrease in nutritive value, for example as milk and meat extender; for diets low in quantity and quality of protein and deficient in calories, soybeans, as full-fat flour, provide both. Because of cultural eating habits, it is difficult to conceive the use of soybeans as complete substitutes of common beans; therefore, efforts should be made to use soy protein in combination with common foods used by populations to whom soybeans are foreign food. Examples of the nutritional benefits derived from the use of soybean protein as flour or protein concentrate or as full-fat soybean flour are given, particularly for foods consumed in Latin American countries.

5. Collins, J.L. and Sanders, G.G. 1976. Changes in trypsin inhibitory activity in some soybean varieties during maturation and germination. J. Food Sci. 41:1, 168-172.

Abstract: Trypsin inhibitory activity (TIA) of four varieties of soybeans was measured. Values (mg/g soybean) represent TIA extracted under conditions employed and are equivalent to a weighed amount of crystallized soybean trypsin inhibitors(TI). As the beans matured, the amount of TIA in the extract increased. Dare variety had the sharpest increase, 13.4-27.5 mg/g. Mean mg/g of TI for Kanrich was 22.5; Verde, 21.7; Soylima, 17.5; and Dare, 21.8. Dehulled beans held 2.5 min in boiling water had 97-98% of the extractable TIA destroyed. Rinsing beans in water removed up to 10.2% TIA. Removing the testa from unrinsed beans reduced TIA up to 4.3%. Decorticated, rinsed cotyledons retained 50.9% (Soylima) to 80.6% (Verde) of the extractable TIA. Beans which were soaked, germinated 3 days and rinsed twice daily lost up to 13.2% TIA.

6. Ferretti, R.J. and Levandes, O.A. 1976. Selenium content of soybean foods. J. Agric. Food Chem. 24:1, 54-56.

Abstract: The selenium content of a variety of soybean-based foods was determined fluorometrically. Several soybean meat analogues averaged 0.375 ug of Se/g, whereas their meat counterparts contained an average of 0.205 ug/g, both well

above the level of 0.10 ug/g believed to be nutritionally desirable. However, two meat extenders based on textured soy protein contained less than one-third the 0.199 ug/g found in ground beef. A canned soy-based chicken-style product had a nutritionally adequate concentration of selenium similar to that found in chicken breasts but several other soy-based products were below this level. A close correlation was observed between the protein content and the selenium content of a series of soybean derivatives. It is concluded that although some soybean analogues contain levels of selenium that are comparable to those in the corresponding ordinary foodstuffs, others do not; therefore, all soybean-based products cannot be considered reliable sources of this essential trace element.

7. Hamdy, M. 1974. The nutritional value of vegetable protein. Chem tech, 4:10, 616-622.

Summary: The author reviews studies on the biological and nutritive value of textured soy proteins, their effects on humans, and certain quality assurance aspects, including insect infestation and microbial counts. Included are the different parameters used to express soy protein nutritional value, the nutritional qualities of lipids, carbohydrates and minerals in soy products.

8. Hamdy, M.M. 1974. Nutritional aspects in textured soy proteins. J. Am. Oil Chem. 51:1, 85A-90A.

Abstract: Textured soy protein products have found extensive use in pet foods and many human foods. They extend and complement meats in formulated foods. Numerous feeding tests with people and experimental animals show that biological values are high and protein efficiency ratios compare favorably with pure meat products. By careful processing of the textured soy products, high quality, safe, low cost protein food can be prepared. Textured soy proteins are an excellent example of man's creative ability to engineer a supplementary food that is nutritious, palatable, and economical.

9. Kakade, M.L., Rackis, J.J., McGhee, J.E. and Puski, G. 1974. Determination of trypsin inhibitor activity of soy products: a collaborative analysis of an improved procedure. Cereal Chem. 51:376.

Abstract: A more accurate and reproducible procedure is described for measurement of trypsin inhibitor activity of soybean products than the method developed by Kakade in 1969 for measuring antitryptic activity in raw soybeans. Because the modified procedure is particularly suitable in determining trypsin inhibitor activity of heat-processed samples, it is recommended for use in evaluating the heat destruction of trypsin inhibitors in soybean samples.

10. Kakade, M.L. 1973. Contribution of trypsin inhibitors in unheated soy in rats. J. Nutrition 103:12, 1772-1777.

Abstract: The trypsin inhibitors present in a crude extract of unheated soybean flour were selectively removed by passage through a column of Sepharose-

bound trypsin. This inhibitor-free extract was fed to rats at a level of 10% protein and evaluated with respect to protein efficiency ratio (PER), weight of the pancreas, and protein digestibility. A comparison was made with the original extract from which the inhibitor had not been removed, both in its native and heated states. From the results obtained it could be concluded that approximately 40% of the growth-depressing as well as 40% of the pancreatic hypertrophic effect of the original unheated extract could be accounted for by the trypsin inhibitors. No difference in the digestibility of the protein in vivo were observed as a consequence of the removal of the inhibitor or by heat treatment. In vitro digestion studies, however, showed that the trypsin inhibitors accounted for only about 40% of the increased resistance of the protein of the original extract to attack by trypsin. It is believed that the reduced PER and pancreatic hypertrophy that persist in the absence of the trypsin inhibitor are primarily due to the refractory nature of native protein to attack by trypsin unless denatured by heat treatment.

11. Kapoor, A.C. and Gupta, Y.P. 1975. Biological protein and effect of amino acid supplementation. J. Food Sci. 40:6, 1162-1164.

Abstract: Three popular Indian varieties of soybean (Bragg, Punjab-1 and Lee) were biologically evaluated for their protein efficiency ratio, digestibility, biological value, net protein utilization, protein value, net protein rentention and protein retention efficiency. Punjab-1 has the highest values of these parameters and Bragg the lowest. These varieties were unable to provide sufficient amounts of methionine and tryptophan to meet the minimum daily requirements for growing rats. Supplementation of flour of Bragg with DL-methionine (0.3%) and L-tryptophan (0.1%) in diets, significantly improved the values of these nutritional parameters, and also the total amount of available methionine and tryptophan was increased.

12. Kies, C. 1974. Nutritional implications of textured protein products. Cereal Sci. Today 19:10, 450-452.

Summary: A review is given on the nutritional impact of soy usage including protein evaluation, influence of heat and alkali treatments, cholesterol content, effect of phytates, and the problem of flatulence.

13. Kies, C. and Fox, H.M. 1973. Effect of varying the ratio of beef and textured vegetable protein nitrogen on protein nutritive value for humans. J. Food Sci. 38:7, 1211-1213.

Abstract: The project objective was to obtain information on which to base protein equivalency curves on the replacement value of TVP protein for beef protein. During five randomly arranged periods of five days each, nitrogen intake from test sources was maintained constant at 4.0 g nitrogen/subject/day supplied by the following ratios of beef to TVP nitrogen: 4/0, 3/1, 2/2, 1/3 and 0.4. Nitrogen balances of eight adult human subjects while receiving these diets were

as follows: -0.44, -0.56, -0.75, -0.90 and -1.11g nitrogen per day, respectively. No mutual supplementation effect was demonstrated, hence, values were predictable on a simple ratio basis.

14. Korslund, M., Kies, C., and Fox, H.M. 1973. Comparison of the protein nutritive value of TVP, methionine-enriched TVP and beef for adolescent boys. J. Food Sci. 38:4, 637-638.

Abstract: The protein nutritional value of an extruded soybean product resembling beef (TVP), a 1% DL-methionine-enriched TVP product and beef for adolescent boys was compared. The experimental diets supplied food energy to approximately maintain weight and were supplemented with vitamins and minerals. Mean nitrogen balances of subjects fed 4.0 g nitrogen as TVP, methionine-enriched TVP, or beef in successive six day periods were -0.08, +0.48 and +0.32 g per day, respectively. Nitrogen retention was significantly higher in response to methionine-enriched TVP or beef than to TVP alone.

15. Lunes, I.E., 1976. Legume toxins in relation to protein digestibility—a review. J. Food Sci. 41:5, 1076-1081.

Abstract: Proteins capable of inhibiting the proteolytic activity of digestive enzymes are common constituents of legumes. These protease inhibitors are generally believed to be largely responsible for the poor digestibility of the protein of legumes which have been inadequately cooked. This reduction in digestibility is invariably accompanied by an enlargement of the pancreas. Recent studies in the author's laboratory, however, have revealed that only about 40% of the growth-depressing activity and a similar fraction of the pancreatic hypertrophic effect of unheated soybeans can be attributed to the action of the trypsin inhibors. The poor digestibility and pancreatic hypertrophy that cannot be accounted for by the trypsin inhibitors are most likely the consequence of the refractory nature of the undenatured protein to attack by trypsin. The phytohemagglutinins also play an important role contributing to the poor nutritive value of some legumes, particularly those belonging to the genus Phaseolus. In this case the phytohemagglutinins are believed to exert a non-selective adverse effect on the absorption of nutrients from the intestional tract rather than a direct effect on the digestive process.

16. Okubo, K., Waldrop, A.B., Iacobussi, G.A., and Myers, D.V., 1975. Preparation of low phytate soybean protein isolate and concentrate by ultrafiltration. Cereal Chem. 52:2, 263-271.

Abstract: Phytate removal from isolates and concentrates is advantageous because phytin phosphorus appears to be unavailable to monogastric animals, and thus interferes with the adsorption of nutritionally essential multivalentcations such as calcium, iron, and zinc. Phytate-protein complexes, which can vary in composition, compound the problem of isolation of pure protein components by altering both the electrophoretic mobility as well as decreasing the solubility of the proteins themselves. A process is described for removal of phytate from

defatted soybean meal and meal extracts to produce low-phytate protein concentrates and isolates. The process consists of two steps: (1) dissociation of phytate from protein: (2) removal of the dissociated phytate from the protein by ultrafiltration using a membrane permeable to phytate but impermeable to protein. Conditions for phytate dissociation were established above, below, and at the isoelectric point of soybean globulins (pH 4.9). At pH 8.5 where multivalent cations such as calcium ion appear essential for the integrity of the protein-phytate complexes, ethylenediamine tetraacetic acid (EDTA) effected dissociation. At pH 3 calcium ion resulted in phytate dissociation. At pH 5 to 5.5 and 65°C the indigenous phytase present in the meal and meal extract promoted continuing dissociation of the complex by enzymatic hydrolysis of the dissociated phytate. Subsequent removal of phytate and other low-molecular-weight impurities by ultrafiltration thus afforded low-phytate soybean isolates and concentrates of high protein content.

17. Rackis, J.J., McGhee, J.E., Liener, I.E., Kakade, M.L. and Puski, G., 1974. Problems encountered in measuring trypsin inhibitor activity of soy flour. Report of a collaborative analyses. Cereal Sci. Today 19:11, 513-516.

Abstract: A collaborative study by a Committee on Soybean Trypsin Inhibitor Analysis revealed that several factors affect both accuracy and reliability of the procedure used to determine trypsin inhibitor activity in raw and heat-treated soy flours. Benzoyl-DL-arginine-p-nitroanilide was the substrate used to measure antitryptic activity of the soybean samples. The relative standard deviation (RSD) between collaborators analyzing extracts prepared in their own laboratories was ±48% compared with an RSD of about ±5% for common extracts. Changes in the procedure which greatly improved agreement between collaborators included extraction with 0.01N sodium hydroxide, and dilution of the extracts within narrow limits to control the level of trypsin inhibitor activity taken for analysis and selection of conditions to eliminate cloudiness or reduction in absorbance values after reaction was terminated.

18. Rackis, J.J., 1974. Biological and physiological factors in soybeans. J. Am Oil Chem. Soc. 51:1, 161A-174A.

Abstract: There are limitations to which one is justified in drawing broad generalizations concerning the diverse biological and physiological effects of soy protein products. Nevertheless, there appear to be two distinct situations: (a) Proper heat treatment exerts a beneficial effect upon the nutritive value of whole soybeans, full-fat and defatted meal. Associated with proper heating is inactivation of trypsin inhibitor and other heat-labile factors and conversion of raw refractory proteins to forms that are more readily tested. (b) Moist heat also has a beneficial effect upon the nutritive value of soy protein isolates. However, a deficiency of certain essential nutrients and the interaction of phytic acid with protein, vitamins, and minerals during processing are the primary factors responsible for the poor nutritive value of soy isolates. Occasionally mineral deficiency symptoms do occur in animals fed soybean meal. It is a misnomer to refer to the growth-inhibiting and pancreatic hypertrophic

properties as a "toxic" effect since both properties are reversible. Modern analytical techniques should be used to reinvestigate the relationship between phytic acid and availability of minerals and vitamins in soy protein isolate diets. Research also is needed to determine more accurately vitamin and mineral contents of soy protein isolates and the availability of vitamins and minerals in soy protein concentrates. Breeding soybean varieties genetically deficient in antinutritional and nonflatulent factors does not appear promising. More research is needed to determine whether fermentation and enzyme processes can be used to prepare flatulent-free soy products. Minor factors to be considered in assessing the nutritive value of soy products include a weak goitrogen present in soybeans, and a very low estrogenic activity.

19. Shemer, M., Wei, L.S., and Perkins, E.G. Nutritional and chemical studies of three processed soybean foods. J. Food Sci. 38:1, 112-115.

Abstract: Three different processing methods were used to prepare foods based on whole soybean. Product A was prepared by soaking the beans overnight, blanching at 210°F for 20 min., blending and drum-drying at 40 psig steam. Product B was water-packed canned soybeans, blanched at 210°F for 20 min. and thermally processed in cans at 250°F for 60 min., then blended, frozen, and freeze dried. Product C, a mixture of soy and banana (1:1 solid basis), was prepared by the same method as Product A. The amino acid composition of the three products determined by gas chromatography was compared. The thermally processed product (B) showed a considerable decrease in methionine compared to Product A (from 23.4 to 11.3 mb Met/g protein). Product A showed superior quality (PER = 23.4; NPU = 46.3), but as a result of methionine supplementation (0.5%) the PER of the thermally processed product (B) was increased from 1.61 to 2.94 and the NPU from 33.2 to 49.3. The effect of the different processing procedures on the quality of the end products, such as browning, nitrogen solubility index (NSI) and amino acid partition between the soluble and the nonsoluble fractions was compared. Product (A) was superior to the thermally processed product (B) considering browning (A = 0.072 compared to 0.156), but was inferior considering NSI (14.92% compared to 23.89%). Amino acid analysis of the soluble fraction indicated a relatively high amount of soluble lysine (114.5 mg/g protein). Cost analysis of the three products shows their economic advantage compared to casein as a protein source.

20. Shemer, M. and Perkins, E.G. 1975. Degradation of methionine in heated soybean protein and the formation of B-methylmercaptopropionaldehyde. J. Agric. Food Chem. 23:2, 201-208.

Abstract: Methionine, added to soy protein isolate, when heated in boiling water is destroyed under aerobic conditions. A portion of the added methionine was degraded to the corresponding B-methylmercaptopropionate. This was determined by gas chromatographic separation of the butyl ester of heated soybean protein hydrolysate. A characteristic peak was eluted after 15:30 min from the heated protein hydrolysate. The mass spectrum of this peak indicated

that it was n-butyl B-methylmercaptopropionate.

21. Skurray, G.R. and Osborne, C. 1976. Nutritional value of soya protein and milk coprecipitates in sausage products. J. Sci. Fd. Agric. 27:2, 175-180.

Abstract: Sausages containing 60% of meat proteins replaced with soybean or milk calcium coprecipitates were prepared. Growth rates and plasma amino acid levels in rats fed diets based on these products, together with vitamin and available amino acid analysis indicated that the nutritional values of the non-meat proteins were similar but were both markedly lower than meat sausages. Nutritional damage to the protein in the sausages during cooking was only apparent in the all-meat sausage.

22. Van Beek, L., Feron, V.J. and DeGroot, A.P. 1974. Nutritional effects of alkali-treated soy proteins in rats. J. Nutrition 104:12, 1630.

Abstract: Alkali-treated spun soy isolate was fed to rats at dietary levels of 5, 10, and 20 per cent for ninety days. No adverse effects are reported for general appearance, growth, feed efficiency, hematologic indexes, blood serum values, urine composition, kidney function, organ weights, and gross and microscopic pathology, except for an increase in both the relative kidney weights and degree of nephrocalcinosis in females only. These renal changes, however, were shown to be related to the high dietary level of available phosphorus. Renal cytomegalia was not observed.

E. Soy proteins: Physical, chemical and sensory evaluations of soy extended food products.

1. Anderson, R.H. and Lind, K.D. 1974. Retention of water and fat in cooked patties of beef and beef extended with textured vegetable proteins. Food Technol. 29:2, 44-45.

Summary: Beef patties were examined with and without the addition of 25% hydrated soy flour to determine if the apparent difference in juiciness was due to the retention of fat and/or moisture in the extended product. Levels of fat ranged from 15 to 35% in both the extended and all beef patties. Results showed that regardless of the initial fat and moisture levels, those composed of a mixture of 25% by weight of hydrated soy in beef retained a greater percentage of moisture and a lesser percentage of fat.

2. Baldwin, R.E., Vandepopuliere, J.M., Russell, W.D. and Korschger, B.M. 1974. Palatibility of turkey and beef with soy. Poultry Sci. 53:5, 1889.

Abstract: Sensory evaluations were conducted on ground turkey and beef patties containing 0 (control), 10, 20 and 30 percent soy protein. Patties were evaluated by untrained panelists on a 5-point scale for aroma, flavor and juiciness. Also, evaluations were conducted on entrees containing 20, 30 and 40 percent soy protein as a replacement for ground turkey. Statistical analyses revealed no significant differences between mean scores for flavor of both turkey and beef patties containing 0 and 10 percent soy or between those containing 20 and 30 percent soy. This same trend was apparent for aroma of beef patties. However, aroma of the control turkey patties was rated significantly more desirable than patties containing 10 percent soy, and aroma for both of these was rated significantly better than aroma of patties containing larger amounts of soy. All of the turkey patties containing soy were rated significantly less juicy than the control but no such difference was found among beef patties. In some of the entrees investigated, as much as 40 percent soy was substituted for turkey without significantly lowering scores for aroma, flavor and general acceptability.

3. Bowers, J.A. and Engles, P.P. 1975. Freshly cooked and cooked, frozen reheated beef and beef-soy patties. J. Food Sci. 40:3, 624-625.

Abstract: Ground beef and beef-soy (15 and 30% soy) patties were prepared and frozen raw or cooked and then, after cooking or reheating were evaluated by a taste panel. Percentages of moisture and fat and TBA values were determined. Adding soy decreased cooking losses, and the reheating process increased cooking losses. Beef patties contained less moisture but more ether extract and had higher TBA values than beef-soy blends. Beef patties were less firm and their meaty flavor and aroma were more intense than those of beef-soy patties but their cereal-like flavor and aroma were less intense. Reheated beef-soy patties had less stale flavor and aroma than reheated beef patties.

4. Cassens, R.G., Terrell, R.N. and Couch, C. 1975. The effect of textured soy flour particles on the microscopic morphology of frankfurters. J. Food Sci. 40:5, 1097-1098.

Abstract: The addition of coarsely and finely divided textured soy flour to a frankfurter batter caused some of the lipid globules to assume an irregular or angular shape. Lipid was not incorporated into the interstices of the texturized soy flour.

5. Cox, C.B. 1974. The huge potential of vegetable protein. Western Meat Industry, June, 1974, 35-37.

Summary: One major meat processor has found that 50% of meat protein in some processed items can be successfully substituted with vegetable protein. On a weight basis it would be higher. Flavors or spices are added. Using soy protein could increase production of comminuted meat products from 7,663 million pounds to 11,681 million pounds or 52%. The barriers are consumer attitudes, federal regulations, and resistance of the industry to change.

6. Cross, H.R., Stanfield, M.S., Green, E.C., Heinemeyer, J.M., Hollick, A.B. 1975. Effect of fat and textured soy protein content on consumer acceptance of ground beef. J. Food Sci. 40:6, 1331-1332.

Abstract: Beef patties were formulated containing 0, 12.5 and 20% textured soy protein (TSP) at two fat levels (22 and 25%). Patties were presented to consumer panels at three locations (Washington, D.C.; Pittsburgh, PA; and Beltsville, MD) for taste testing. Tenderness decreased with increased fat content, but increased with added TSP. Generally, patties with added TSP were more tender than those without, regardless of the fat level. Differences in flavor, aroma, appearance and overall acceptance were nonsignificant. Patties with 12.5 or 20.0% TSP were rated equal or superior in palatability to all-beef patties. Males rated patties significantly higher for flavor, appearance and overall acceptability than females. Data from the present study suggest that ground beef containing up to 12.5 or perhaps 20% TSP is comparable in palatability to all-beef patties.

7. Crowley, P.R. 1975. Practical feeding programs using soy protein as base. J. Am. Oil Chem. Soc. 52:4, 277A-279A.

Abstract: The U.S. has furnished billions of pounds of food commodities containing soy protein for use in feeding programs in the less developed countries. As a result of the low cost, excellent nutritional qualities and functional versatility of soy products, they have been used extensively as protein additives in a broad spectrum of foods for practical feeding programs. Soy flours are a major ingredient in blended foods, such as instant corn soy milk, corn soy blend, and wheat soy blend; and soy flours and grits have been used as protein fortificants in wheat, corn, sorghum, and oat products distributed overseas. Most recently, a new whey soy drink mix has been developed for use in preschool feeding programs and now is being introduced around the world. As more attention

focuses on the nutritional requirements of feeding program beneficiaries and on the need for low cost sources of protein, it can be expected that uses for soy protein will expand and additional soy based foods will be added to the list of commodities used in practical feeding programs.

8. Drake, S.R., Hinnergardt, L.C., Kluter, R.A. and Prell, P.A., 1975. Beef Patties: The effect of textured soy protein and fat levels on quality and acceptability, J. Food Sci. 40:5, 1065-1067.

Abstract: Ground beef patties were formulated to contain 0, 15, 20, and 25% added textured soy protein at each of four fat levels (15, 20, 25, 30%). Analysis of the raw patties for fat found the Hobart Fat Percent Indicator and the Soxhlet extraction procedures reporting essentially the same fat values. Total cooking losses were found to be less with the addition of soy protein. Fat loss upon cooking was dependent on the amount of fat in the patty and not on the soy protein level. Moisture loss during cooking was highly dependent on the level of soy protein incorporated in the beef patties. Both trained and consumer sensory panels differentiated among patties with various levels of soy protein on the basis of flavor. No distinction among patties was made due to fat levels.

9. Goltry, S.J., Stringer, W.C. and Baldwin, R.E. 1976. Sensory evaluation of pork sausage containing textured vegetable protein. J. Food Sci. 41:4, 973-974.

Abstract: The objective of this study was to evaluate the flavor, juiciness, and general acceptability of pork sausage containing four levels of textured vegetable protein (TVP). The different formulas were evaluated, one at a time, under red lights, and sensory evaluations of juiciness, flavor, and general acceptability were made on a 5-point hedonic scale (1, like very much to 5, dislike very much). Mean panel scores for flavor indicated the formula containing 10% TVP was most liked, followed in order by the control, 20% and 30%. However, the control and 10% treatment were superior to the 20 and 30% treatment. Judgment of juiciness indicated a significant difference between the 10% and 20% treatment, but no significant difference could be detected when comparing either the control or 30% treatment to the 10% and 20% treatments. There was no significant difference among any of the treatments of general acceptability, but the 10% was most liked by the panelists followed by the control, 30% and 20%. Mean panel scores for flavor, juiciness and general acceptability revealed that none of the treatments were disliked. The 10% treatment was the most preferred of the four treatments when flavor, juiciness, and general acceptability were evaluated.

10. Judge, M.D., Haugh, C.G., Zachariah, G.L., Parmalee, C.E., and Pyle, R.L. 1974. Soya additives in beef patties. J. Food Sci. 39:1, 137-139.

Abstract: Research was conducted to evaluate the effects of two soya products (soya flour and soya protein concentrate) on several measures of quality

in ground beef patties. The results indicated that the initial levels of fresh meat spoilage organisms were increased slightly by the soya flour. However, neither the flour nor the soya protein concentrate resulted in increased bacterial numbers at the end of a 7-day storage period. Ground meat containing the soya products in combination with 20% fat had greater light reflection than control samples. With meat containing 30% fat, the soya protein concentrate increased light reflection in patties that were stored for at least 3 hr in the unfrozen state, whereas, the soya flour decreased the reflection under all storage conditions tested. The soya additives decreased cooking shrinkage in all tests conducted. At high levels of use the flour reduced shrinkage to a greater extent than the concentrate, but at low additive levels, the shrinkage was nearly identical between the two soya products. Patties that had been frozen shrank more than unfrozen patties. The ease of removal of interleaving paper from frozen patties was highly dependent on the fat content of the meat. Whereas, the soya additives had no effect on paper release force in patties containing 20% fat, the additives increased the force required for paper removal from those containing 30% fat.

11. Karmas, E. and Turk, K. 1976. Water binding of cooked fish in combination with various proteins. J. Food Sci. 41:4, 977-979.

Abstract: Water binding of cooked fish was determined in combination with (a) sodium, calcium, potassium and isoelectric form of soy protein isolate; (b) sodium and calcium whey protein concentrate; and (c) sodium caseinate. The sodium proteins were added at 0%, 2%, and 5% level, the other proteins at 0% and 2% level. Water binding was determined with a gravimetric adaptation of the filter paper press method. All proteins increased the water binding of cooked fish. The fresh and 2-yr old samples of sodium soy proteinate were significantly better water binders than the same proteinate aged for 8 years. The ions associated with the soy and whey proteins did not affect the water binding significantly. Sodium soy proteinate and sodium caseinate were both better water binders than the sodium whey proteinate.

12. Kluter, R.A., Hinnergardt, L.C., and Brockmann, M.C. 1977. A storage study of six commercial soy protein ingredients combined with ground beef. Technical Report in press. Natick Research and Development Command, Natick, MA. Natick/TR-77/020

Summary: Six soy protein brands were investigated over a nine-month period of storage at -17.8°C. Two levels, 20% and 30% hydrated soy were used in frozen ground beef patties. Consumer panel results indicate the possibility of use at 20% hydrated levels, even though all beef patties were rated higher. Addition of 30% hydrated soy is not recommended. One brand of soy was rated higher than the others and textured soy flour was generally rated higher than soy protein concentrates. Storage time did not significantly affect the ratings of the frozen patties. When condiments were added the effects of soy protein additions were masked.

13. Kotula, A.W., Twigg, G.G. and Young, E.P. 1976. Evaluation of beef patties containing soy protein, during 12-month frozen storage. J. Food Sci. 41:5, 1142-1147.

Abstract: Patties containing 20 or 30% of soy protein (textured or concentrate) were stored at -17°C and evaluated tri-monthly for 1 yr for effects of storage on organoleptic properties and chemical changes. Textured soy proteins from four manufacturers and concentrate from two manufacturers were tested. Fat content was about 20% for all patties. A 52-member panel of adults, from 18 to 60 years of age, evaluated (without condiments) the 12 types of patties with soy and the all-meat patties. A 13-member panel evaluated the effects of condiments on acceptability. Chemical tests included proximate analysis (ash, fat, moisture and protein), pH, peroxide values and thiobarbituric acid (TBA) number. Mean scores for flavor, aroma and overall acceptability of the patties dod not change significantly during the year of frozen storage. Some differences were significant in scores for tenderness, appearance and juiciness, but they were too small to be of practical importance. The addition of condiments to patties did not improve the scores for appearance and juiciness but did improve scores for flavor, aroma, tenderness and overall acceptability. Throughout the year, patties containing soy concentrate at either 20 or 30% rated significantly lower than most of the patties containing textured soy protein and the all-beef patties when evaluated for flavor, appearance, aroma and overall acceptability. Although compositional changes in patties were evident during 12 months of storage, their magnitudes were inconsequential. Peroxide and TBA values increased during storage at a faster rate for all-beef patties than for patties containing soy protein. Some panelists were able to detect old or rancid condition in some products during the 9- and 12-month storage but most palatability traits were not significantly different in patties that had been stored for up to 12 months. Soy protein additives tended to inhibit rancidity development.

14. Kotula, A.W., Twigg, G.G. and Young, E.P. 1976. Evaluation of frozen beef patties containing soy protein, Maryland and University of Maryland, College Park, Maryland. Technical Report No. 75-80 FEL.

Summary: This is the technical report containing the details reported in the preceding reference.

15. Levinson, A.A. and Lemancek, J.F. 1974. Soy protein products in other foods. J. Am. Oil Chem. Soc. 51:1, 134A-137A.

Summary: Both long-term and emerging patterns of utilization underscore the diversity of the use of soy protein products in processed foods other than meat foods. This paper presents a selective overview of this diverse usage. Such uses are in dairy products, baked goods, breakfast cereals, baby foods, beverages, snack foods, confectionaries, gravies, soups, baked beans, and pasta products.

16. McCloud, J.T. 1974. Soy protein in school feeding programs. J. Am. Oil Chem. Soc. 51:1, 141A-142A.

Abstract: Textured vegetable protein has been a tremendous asset to the Memphis school feeding program. There are several reasons for this: (A) it is a dry product, easy to handle and store; (B) shelf life is long enough to permit quantity purchasing and warehousing; (C) dry storage of textured vegetable protein is much cheaper than refrigerated storage of meats; (D) students have not objected to its use; (E) the absorption qualities of the textured vegetable protein allow purchase of ground beef with a 30% fat content, rather than a 22% fat content; (F) it allows a more innovative approach to school food services; and (G) it saves money. The introduction of textured vegetable protein into this operation has saved the U.S. school lunch program millions of dollars.

17. Moore, S.L., 1976. Effect of salt, phosphate and some nonmeat proteins on binding strength and cook yield of a beef roll. J. Food Sci. 41:2, 424-426.

Abstract: Beef rolls were prepared with coarse-ground beef (25.4 mm plate), 8% added water and either salt, salt plus 0.25% sodium tripolyphosphate (TPP), soy isolate, textured soy protein and modified whey solids at 1, 2 or 3% levels. Binding strength was measured with an Instron as the amount of force necessary to break a beef roll across bridge widths of 75, 100, 125 and 150 mm. Binding strength increased as salt content increased from 1% to 3%. Cook yield increased from 79% with 1% salt to 93% with 3% salt. The addition of 0.25% TPP resulted in an additional increase in binding strength. Cook yield increased from 93% with 1% salt plus 0.25% TPP to 98% with 3% salt plus 0.25% TPP. The modified whey solids at 2% level had the highest binding strength of the non-meat protein materials added. This was similar to 2 or 3% added salt. The soy isolate at 3% level resulted in the highest cook yield, 78%.

18. Nielsen, L.M. and Carlin, A.F. 1974. Frozen precooked beef and beef soy loaves. J. Am. Diet. Assoc, 65:1, 35-40.

Abstract: After storage at -4°F for zero, two, four, or six months, frozen raw or precooked beef loaves were compared with precooked, frozen beef-soy loaves containing 30 per cent hydrated, fortified, textured soy. Total losses during precooking to 165°F internal temperature and reheating to 130°F were 18 and 8 percent for beef and beef-soy loaves, respectively. Beef-soy loaves were less juicy and had a pronounced soy flavor. Fat percentage in ground chuck from which the loaves were made was 27; in raw loaves, it was 17 in beef and 13 in beef-soy: but in both beef and beef-soy precooked and reheated loaves, it was 12 per cent. Thiamine retention (moisture-free basis) in reheated samples was higher for all-beef loaves — 0.37 mg. per 100-g serving-compared with 0.29 mg. for beef-soy loaves.

19. Rakosky, J. Jr. 1974. Soy grits, flour, concentrates, and isolates in meat products. J. Amer. Oil Chem. Soc. 51:1, 123A.

Abstract: Because of changing attitudes of consumers, processors, and regulatory agencies, soy protein products are being used at an increasing rate in various processed meat systems. The use of basic soy protein products in several meat systems is examined and guidelines are presented to optimize their use. Soy products as a supplemental ingredient in various meat systems can contribute nutrition, flavor, and valuable functional properties. As the price of meats continues to rise, and consumer interest in nutrition continues to increase, their demands will prompt governmental agencies to reconsider present meat regulations.

20. Roberts, L.H. 1974. Utilization of high levels of soy protein in comminuted meat products. J. Amer. Oil Chem. 51:1, 195A.

Summary: To utilize soy proteins at a 40-75% replacement level in comminuted processed meat products, the most important factor is the structure forming characteristic. Although tests for water solubility, water absorption, emulsifying, gelling and coagulating tests can be made, they will not exactly predict the structure formation. The canned meatless emulsion test employed by Armour may be effective in predicting structural quality.

21. Schweiger, R.G. 1974. Soy protein concentrates and isolates in comminuted meat systems. J. Amer. Oil Chem. 51:1, 192A-194A.

Summary: This paper describes the results of the use of soy protein isolate and soy protein concentrate in coarsely and finely ground meat systems to prevent excessive water and fat losses in frankfurters, sausages and meat patties. About 6 to 10% soy protein concentrate and 20% fat would be optimum in meat patties from a palatability, nutritional, and economic view point. In frankfurters, overall acceptability decreased when 10% protein products were substituted with isolated soy protein.

22. Shafer, M.A. and Zabik, M.E. 1975. Dieldrin, fat and moisture loss during the cooking of beef loaves containing texturized soy protein. J. Food Sci. 40:5, 1068-1074.

Abstract: Texturized soy protein ranging from 0-5% was substituted for beef in a meat-loaf system to determine the effects of soy on fat, moisture and pesticide reduction during cooking. The beef used in the study was environmentally contaminated with dieldrin. The addition of texturized soy to the meat-loaf system reduced fat losses through the drip but did not reduce moisture losses during cooking. With all levels of soy substitution, the dieldrin content of the cooked meat loaves was less than that of the corresponding raw meat loaves. The reduction in dieldrin content was dependent on both drip losses and codistillation. The amount of dieldrin found in the drip decreased as the level of soy substitution in the meat loaves increased. Significant decreases in dieldrin content, however, were accompanied by codistillation and volatile losses.

23. Shelef, L.A. and Morton, L.R. 1976. Soybean Protein Foods. Use and acceptance in institutional feeding. Food Technol. 30:4, 44-50.

Summary: One hundred institutional food services in Metropolitan Detroit were surveyed in 1974. Only 15 used soy protein in their feeding program. Further study of the 15 revealed that most used flavored or unflavored dry granules in a proportion of 5-30% (hydrated). The users were schools (6), hospitals (4), nursing and convalescence centers (3) and industry (2). Most soy products were used as extenders in meat, fish or poultry products. Most administrators felt the soy extended foods were well liked, although some felt the flavored products were too spicy and salty.

24. Smith, G.C., Marshall, W.H., Carpenter, Z.L., Bransan, R.E., and Meinke, W.W. 1976. Textured soy proteins for use in blended ground beef patties. J. Food Sci. 41:5, 1148-1152.

Abstract: Three experiments were conducted in which ground beef patties were prepared to contain 20 or 30% fat and 0-50% of rehydrated textured soy protein (TSP). Among patties with 20% fat, those with 20, 25 or 30% of a reference soy protein (TSP 1) were desirable in appearance on the first day of retail display; among patties with 30% fat only those with 20% soy protein (TSP 1) were desirable in appearance of day-1 of retail display. Comparison of 7 brands of textured soy protein revealed differences among blended beef patties in cooking loss, appearance and palatability traits. Not all soy products that were available for these tests were of equal efficacy for use in blended ground beef patties. Selection of an appropriate soy protein can overcome deficiencies in appearance, can materially reduce cooking shrinkage and can be used without significantly detracting from the palatability of cooked beef patties. The choice of a specific soy protein for use in blended-beef patties should be predicated upon organoleptic evaluation of the products under consideration and knowledge of intended form of sale (cooked vs raw). If the product is to be sold in cooked form, the fat percentage should exceed 20% to optimize flavor desirability and overall palatability. If the product is to be sold at retail in the raw form, the combined proportion of fat plus textured soy protein should not exceed 50% of the final batch composition.

25. Spaeth, R.S. 1974. Part IV: Innovative processed soy foods find market in affluent and poor societies. Food product development, 7:9, 92-94.

Summary: Early work in soybean processing is reviewed and usage in the future is predicated. The conclusion is that the world market will absorb as much of the soybean crop as the American farmer can grow and the question is not if textured soy protein will capture a significant part of the meat market, but when and how much.

26. Terrell, R.N. and Staniec, W.P. 1975. Comparative functionality of soy proteins used in commercial meat food products. J. Am. Oil Chem Soc. 52:4, 263A-266A.

Abstract: The use of soy isolates, concentrates, and texturized flours in meat food products is discussed. Functional characteristics of soy products in relation to their market application are reviewed. Soy isolates find more limited usage in meat food systems (2%) than the concentrates and textured soy flours (8–12%). In weak meat systems containing large amounts of fat (30–45%), the concentrate emulsifier and isolate are more important than the texturized soy flour. In chopped meat systems with 18–25% fat, the textural properties of soy flour (extruded) are more important than the use of an isolate. However, combinations of concentrate emulsifier and texturized flour are used. The method of cooking, i.e., fresh, deep fat-fried, or char-broiled, will affect the usage of soy combinations. In comminuted, cooked, cured meat food mixes, soy concentrates, and textured flours currently are being used. Nutritional properties are improved by inclusion of available ingredients high in lysine and methionine. Functional measurements of textural properties have been completed using the Instron with a Lee Kramer cell. Both model emulsion systems and finished product results substantiate the accuracy of textural properties in soy-meat mixes using the Instron.

27. Wilding, M. Dean, 1974. Textured proteins in meats and meat-like products. J. Am. Oil Chem. Soc. 51:1, 128A–130A.

Abstract: The forecasted use of textured soy protein by 1980 is 10–20% of the total beef market. Important factors in the use of textured soy protein are cost control, improved functionality, fat control, and nutrition. Blends of textured soy protein and ground beef give nutritional quality exceeding protein efficiency ratio of 2.5 (casein) in several products evaluated. Animal feeding data are given for these blends. A description of the proper use of soy in meat is given. Bacteriological and color problems are not due to the addition of textured soy but increased temperatures of handling the blended product.

28. Williams, C.W. and Zabik, M.E. 1975. Quality characteristics of soy-substituted ground beef, pork and turkey meat loaves. J. Food Sci. 40:3, 502–505.

Abstract: Ground beef, pork (50:50 mixture of ham and pork) and turkey meat loaves containing 0 to 30% soy-substitution were evaluated for sensory characteristics of flavor, juiciness, mouthfeel and overall acceptability. In addition, cooking losses, moisture content, total lipid and TBA values during short-term storage at 5 or 11°C were determined. 30% soy-substitution did not adversely affect the quality characteristics of the ground beef and turkey systems. However, the soy-substitution did lower the flavor, juiciness and overall acceptability scores of the pork meat loaves. The use of 30% soy-substitution decreased the total and drip loss, whereas it did not affect the volatile losses. Although 30% soy-substituted meat systems appeared to have slightly lower TBA values during refrigerated and frozen storage, soy does not appear to appreciably reduce the amount of TBA reactive compounds developing in the meat systems.

29. Wolford, K.M. 1974. Beef/soy: consumer acceptance. J. Am. Oil Chem. Soc. 51:1, 131A–133A.

Abstract: Significant changes of social pursuits are not easily wrought. We are steeped in traditions which influence every aspect of our behavior. History shows it is difficult to alter these patterns. Food consumption is at the nucleus of this tradition and it is not without difficulty that we successfully introduce major change to our eating habits. Yet this was accomplished within this current year in a great portion of society, and with more than a modicum of success, by the blending of textured soy protein with red meats at the retail store level.

30. Yeo, V., Wellington, G.H. and Steinkraus, K.H. 1974. Effects of soy curd on the acceptability and characteristics of beef patties. J. Food Sci. 39:2, 288–292.

Abstract: Soy curd-beef patties were made containing 0%, 5%, 10%, 20%, 75% and 100% (w/w) of curds which had been pressed at 300 psi, 600 psi and 1100 psi during manufacture. Taste panel tests showed that by increasing pressure on the soy curd or by the addition of flavoring to the curd before patty formation, increases in soy concentration became less detectable and the acceptability of the patties was drastically increased. Soy curd-beef patties made with 1100 psi pressed curd and with color and flavor added were favorably accepted even at levels as high as 75% curd (w/w). The easy detectability of flavored soy in patties did not greatly change the high acceptability of the patties. The chemical composition, functional characteristics and physical properties of the soy-beef patties were also studied.

31. Ziemba, J.V. 1974. Vegetable protein moves into sausage. Food Eng. 46:5, 93–94.

Summary: A meat company has a successful product line of protein-fortified meats. One is a weiner type item, another a bologna type. Using over 3% soy protein flours gave slight off-tastes and mushy texture, but 10% soy-based textured vegetable flake (50% protein) was satisfactory. Only a few minor processing modifications were needed to produce the products.

32. Zeprin, Y.A. and Carlin, A.F. 1976. Microwave and conventional cooking in relation to quality and nutritive value of beef and beef-soy loaves. J. Food Sci. 41:1, 4–8.

Abstract: Beef or soy flavor of meat loaves containing 0, 15% soy flour or 15% soy concentrate were evaluated after cooking in microwave or in conventional ovens. Also, cooking time, cooking losses, fat and moisture content and thiamine retention were determined. Beef or soy flavor was significantly affected ($P < 0.01$) by loaf type, but not by oven treatment. Loaves (960 g) cooked electronically reached $74^{\circ}C$ in 19 min and had consistently higher cooking losses than those cooked conventionally for 78 min. Substitution of 15% soy reduced cooking losses more in loaves cooked in electric than in microwave ovens.

Soy had no effect on the fat content, but cooking had a significant ($P \angle 0.01$) effect; i.e., 11.5% fat in electronically, and 9.6% in conventionally cooked loaves. Thiamine retention was not affected by 15% soy substitution. The average thiamine content, regardless of treatment, was 0.09 mg/100g of the cooked loaves.

33. Analogs and extenders: Life savers for tight budgets. Food Management 10:1, 50.

Abstract: Extensive use of soy protein extenders and analogs has worked successfully at Lake Wales (Fla.) Christian School. Advantages are reviewed, and recipes are featured for the following: cannelloni with beef; ham mousse; fish turnovers; beef pies; chicken with tuna sauce; turkey tetrazzini; chicken hash; and fish pudding. In all of these recipes, the soy protein extenders account for 20 to 30 per cent of the meat. Flavorful seasonings are part of the success of these dishes.

34. Bind properties of isolate reduce meat patty rejects. 1975. Food Processing 36:4, 91.

Summary: A meat company wanted to produce meat patties containing 55% meat and 45% hydrated textured soy granules. Addition of over 35% soy granules caused excessive patty breakage because of poor binding. The addition of soy protein isolate (90% protein) at a 2% level gave the desired binding properties and improved moisture and fat retention.

35. Consumer acceptance of vegetable protein expands opportunities at supermarket level. 1973. Food Processing 34:7, 41-44.

Summary: Food processors are combining soy in fresh ground beef, usually at a 25% rehydrated level. Introductory prices are usually $0.20 per pound less than ground beef at a similar fat level. Peanut flakes, not in production at commercial level, may be used to replace 2/3 of the meat in prepared meat products.

36. Non-standard, high protein formula sells. 1972. Food Processing 33:1, 29.

Summary: Ten percent soy protein concentrate (dry weight) is added to a non-standard frankfurter, increasing the protein content, lowering the fat content and lowering the cost.

37. Operation update: school lunch reviews protein progress, 1973. Food Service Marketing 35:8, 45.

Abstract: More than 250 Illinois school cafeteria personnel participated in a food service workshop which featured soy protein foods. To date, the most

popular uses of the beef-like products are in spaghetti sauce, sloppy Joes, meat loaf, chili, and meat balls. Chicken and ham-like cubes are acceptable in salad plates. Students don't seem to notice the difference when 25 per cent of the dehydrated product is incorporated with 75 per cent meat. Cost advantages were stressed.

38. Problem: How to cut meat costs in half. Solution: meat extenders 1974. Food Management 9:8, 79.

Abstract: Textured vegetable protein products have made it possible to cut meat costs in half at the Lynchburg Training School in Virginia. Lynchburg has become the largest institutional user of textured vegetable protein in the U.S. Four years ago, when residents were adjusting their taste buds to the new products, 40 percent textured vegetable protein was used as an extender. This has been increased to 70 per cent in meat loaves and hamburgers. The Training School complex has a population of 3,104 mentally retarded patients, 141 residents in food-service and 1,900 staff members.

39. Soy combinations: specific protein functions of isolate and textured pieces are combined to improve meat characteristics 1974. Food Processing. 35:7, 34-35.

Summary: Meat patties have been made successfully using two forms of vegetable protein; an improved soy isolate plus minced, textured soy. The combination of soy replaces 30-50% of the meat.

40. Soy isolate improves quality, yield and economics of cured meat. 1976. Food Processing 37:10, 44-46.

Summary: The USDA now permits addition of nonmeat portions to cured meat pieces. A fortified soy isolate, developed specially for this use permits production of cured hams pumped to 135-150%. Hams have been extended up to 50% without detection of soy. The cost is about 11% less than "water added" ham. The isolate is a gelling protein that becomes part of the meat and binds more water and juices than meat proteins. Finished cured meat meets the 17% protein requirement and the PER of 2.0. Isolate is added with the brine solution. A maximum of 10% isolate is a limitation for the stitch injected pumps. Brine must be thoroughly mixed so as not to clog the needles. Labeling would read "Combination Ham Product."

41. Soy protein concentrate reduces meat patty shrink by 1/3. 1976. Food Processing 37:8, 50.

Summary: Meat patties extended with 20% hydrated soy protein concentrate were rated equal to all meat patties on the overall ratings. Flavor of the product used is extremely bland. Beef used in the tests had a fat content of 20%. Shrinkage of the control was 22% vs. a 14% shrinkage for the extended

patty. Recommended usage levels are 20% to 30% hydrated soy concentrates in ground meat applications. Cost savings estimated at 18% using 20% soy concentrate, 26.8% at the 30% level.

42. Soy protein cuts ingredient cost of links and patties 37%. 1976. Food Processing. 37:3, 47-48.

<u>Summary</u>: Many meat processors have completed product development work and consumer testing of pork links and patties containing high levels of textured soy protein. One manufacturer has found it possible to use 40% hydrated soy protein. A lower fat content in the final product is also possible.

43. Soy protein isolate for emulsified meat systems. 1975. Food Processing 36:4, 92.

<u>Summary</u>: A soy protein isolate, developed for replacing salt-soluble meat protein, has gel-forming characteristics of expensive salt-soluble meat proteins when used in emulsified meat systems. The ingredient is recommended for use in sausages, frankfurters, bologna, and other luncheon meats.

44. 20% textured vegetable protein in meat rolls improves yields, cut cost. 1976. Food Processing 37:5, 82.

<u>Summary</u>: Fabricated extended beef, corned beef, pastrami, and ham rolls have been developed and are now in commercial trials. The rolls have been extended with approximately 21% hydrated TVP.

45. Vegetable Protein Fiber adds texture to mechanically deboned meat 1975. Food Processing 36:7, 48-49.

<u>Summary</u>: Structured soy isolates will add texture to mechanically deboned comminuted meat. They are used at approximately 25% of the finished product, cost less than spun protein, have better retort stability, and better pickup of water and fat.

F. Soy proteins; procedures for detecting in food products

1. Coomaraswamy, M. and Flint, F.O. 1973. The histochemical detection of soya "novel proteins" in comminuted meat products. Analyst 98:1 168, 542-545.

Abstract: The enforcement of the regulations governing meat and meat products requires the determination of meat content. Meat content is assessed from the total nitrogen content, from which suitable deductions are made for the nitrogen contributed by the other ingredients of significant nitrogen content present in meat and meat products. The availability of "novel proteins" and the possibility of the addition of these proteins to meat products necessitates the detection and determination of "novel proteins" in such products for the true assessment of their meat content. A microscopical method that indicates the presence of "novel protein" of soya origin in meat products has been examined. This method involves the use of a specific technique to demonstrate the presence of carbohydrate material and is diagnostic for the cellular fraction of many processed soya products.

2. Flint, F.O. and Lewin, Y.A. 1976. The histochemical demonstration of soya products in foodstuffs. J. Food Technol. IFST (UK) 11:2, 137-142.

Summary: A histochemical staining method for showing the carbohydrate constituents of plant tissue was applied to dried soya bean, textured soya proteins, and commercial meat and cereal products containing soya. A description follows including photomicrographs of the cellular material characteristic of soya bean and its products. This shows the incorporation of cellular elements in textured soya products and in foodstuffs to which material of soya origin had been added.

3. Frouin, A. 1974. Detection of soy proteins. J. Amer. Oil Chem. Soc. 51:1, 188A-189A.

Summary: One of four methods is usually employed in the detection of soy beans. The first, the histological method, is simple but does not give formal proof because the natural soybean structure has been damaged. The second, the serological method, has not yet produced a good test. The third, immunoelectrophoresis is precise but the method is complicated. The fourth, electrophoresis, is the most widely used and the best at this time. The author has adapted the electrophoresis test (the Penny-Hoffman method)[1] with some modifications of a technique used by Spell.[2]

1. Penny, I.F. and Hoffman, K. The detection of soya bean protein in meat products, Seventeenth(1971) European Meeting of Meat Research Workers.

2. Spell, E. 1972. Nachweis von Milcheiwertz und Soyaweitz in Fleischerzeugnissen mit silfe der vertikalen flachdisk - electroprorize. Die Fleischwertschaft. 11:145.

4. Lee, Y.B., Rickansrud, D.A., Hagberg, E.C. and Forsythe, R.H. 1976. Detection of various nonmeat extenders in meat proteins. J. Food Sci. 41:3, 589-593.

Abstract: The stacking sodium dodecyisulfate-acrylamide gel electrophoresis method was evaluated for the qualitative detection of various vegetable proteins in meat products. An additional study was also conducted to determine the influence of milk powder, casein, whey protein and egg white proteins on the previously reported electrophoretic procedure for the quantitation of meat and soybean protein content. Soybean, cottonseed flour, cottonseed protein concentrate exhibited their own unique electrophoretic patterns and were clearly identified when they are added to meat proteins singularly or in various combinations. It was also shown that meat and soybean protein can be successfully identified and quantitated in the presence of milk powder, casein, whey and egg white by employing the described electrophoretic method.

5. Lee, Y.B., Greaser, M.L., Rickansrud, D.A., Hagberg, E.C. and Briskey, E.J. 1975. Quantitative determination of soybean protein in fresh and cooked meat-soy blends. J. Food Sci., 40:3, 380-383.

Abstract: The stacking sodium dodecylsulfate-acrylamide gel electrophoresis method was evaluated for the quantitation of soybean protein content in fresh and cooked meat-soy blends. Protein extracts from soy isolates, texturized soy protein, beef and soy-beef blends were electrophoresed on stacking SDS-acrylamide gels, followed by densitometer scanning. Soybean protein exhibited five major bands and four of them were distinctly separated and easily distinguished from meat protein bands. A linear relationship was observed between the amount of soy or meat protein applied on the gel and the peak area of a selected index band. The plotting of protein concentration ratio of soybean/meat protein against the peak area ratio of soybean protein band/meat protein band eliminated experimental variability and presented a reliable linear standard curve in using the established standard curve, the soy protein content in soy-beef blends, containing various levels of beef and soy isolate or texturized soy protein was quantitated within $\pm 2\%$ of actual content. The stacking method employed was superior to other electrophoretic methods, providing good resolution and reproducibility in the separation of meat and soy protein mixture.

6. Lowry, K.L., Caton, J.E., and Foard, D.E. 1974. Electrophoretic methods for detecting differences in seed proteins of soybeans. J. Agric. Food Chem. 22:6, 1043-1045.

Abstract: With the aim of extending the genetic identification of soybean varieties and mutants, gradient polyacrylamide gel electrophoresis has been employed to detect differences in proteins extracted from seeds of the varieties Lee, Pickett, and Harosoy, and three radiation-induced morphological mutants of Harosoy. Of eight solvents compared, a Tris-glycinate buffer

(pH 8.6) with or without 2-mercaptoethanol, extracted the most protein from seedmeals. Sonication extracted more protein into a given solvent than did agitation. Electrophoretic banding patterns of the extracted proteins of a given variety or mutant were qualitatively the same (given bands migrated to the same positions) regardless of solvent or solution method employed, although different relative intensities of bands were observed for the same sample in different solvents. By electrophoresis of the extracted seed proteins on gradient polyacrylamide slab gels, we detected previously unreported differences between Lee and Pickett varieties and discovered that the patterns of two of the mutants were similar to each other but different from that of the other mutant, which was similar to the pattern of the parent Harosoy variety. When the extracts were treated with sodium dodecyl sulfate and 2-mercaptoethanol before electrophoresis on gels containing sodium dodecyl sulfate (1) there were differences in the major proteins or protein subunits of the two mutants that had similar patterns on gradient gels, and (2) the remaining mutant and the three natural varieties shared the same proteins, differing only in the relative amounts present in each.

7. Wilson, J.M., Kramer, A., and Bengera, I. 1973. Quantitative determination of fat, protein and carbohydrates of soy products with infrared attenuated total reflectance. Wilson, J.M., Bengera, I. J. Food Sci. 38:1, 14-17.

Abstract: Attenuated total reflectance (ATR), offering a possible rapid method for quantitative measurements of major nutritional components in food materials (fat, protein, carbohydrates), was employed to evaluate the composition of a variety of soy products. Using a sample cell developed in this laboratory, different sample particle sizes and forces applied to a mounted sample were investigated to determine if variations of this type would improve the accuracy and precision of the quantitative ATR technique. Correlations of 0.96 for fat and 0.94 for protein were achieved between a chemical analysis and the infrared technique using a baseline absorbance (A) calculation and 120 mesh samples at 40-lb force. Errors assignable to various aspects of the ATR technique are discussed.

G. Soy proteins: effect of storage on foods extended with soy

1. Kramer, A., King, R.L. and Westhoff, D.C. 1976. Effects of frozen storage on prepared foods containing protein concentrates. Food Technol. 30:1, 56-62.

Summary: The effects of frozen storage at constant and fluctuating temperatures on the sensory, microbiological, and nutritional qualities of frozen prepared foods containing textured vegetable protein and single cell yeast protein are described. Commercially prepared frozen foods were obtained directly from the manufacturers and included (1) salisbury steak in tomato sauce with no textured vegetable protein, (2) ground beef containing 8.5% textured vegetable protein and (3) ground beef with 8% textured protein and 2% single cell protein. The results indicate that these frozen entrees enriched and extended with 8% vegetable protein as well as 2% single cell protein can be maintained for at least 3 months and usually 6 months if stored at -20°C or lower. Mushiness encountered in the enriched samples decreased rather than increased during frozen storage. Fluctuating temperatures had a detrimental effect but nutritional value was generally maintained, microbiological levels decreased with time but less so in samples containing the single cell protein.

2. Obioha, I.W., 1976. Bacteriological quality of ground beef and soy extended ground beef. Master's degree thesis, Iowa State University, Ames, Iowa.

Summary: Tests were carried out on the bacterial content of retail ground beef and ground beef extended with soy to determine the effects of freezing, frozen storage (up to 56 days), and subsequent thawing. The conclusions were that soy additives had no significant effect on the growth or multiplication of staphylococci, but did enhance the growth of anaerobes in frozen and non-frozen meat.

3. Pratt, D.E., 1972. Water soluble antioxidant activity in soybeans. J. Food Sci. 37:2, 322-323.

Abstract: Fresh and dried soybeans possess both prooxidant and antioxidant activity. Upon heat inactivation of lipoxidase the beans possess considerable antioxidant activity. Commercial preparations of soy protein concentrate and defatted soy flour also contained potent antioxidant activity in lipid-aqueous systems. SPC and defatted soy flour possessed greater antioxidant activity than either fresh or dried soybeans even when extracted in the same manner.

4. Sangor, M.R. and Pratt, D.E. 1974. Lipid oxidate and fatty acid changes in beef combined with vegetables and textured vegetable protein. J. Amer. Diet. Assoc. 64:3, 268-270.

Abstract: Antioxidation in beef lipids due to extracts of textured

soy vegetable protein, vegetables alone, and vegetables plus textured vegetable protein, as well as in beef-vegetable soup, was studied by determining the thiobarbituric acid (TBA) number after differing storage periods. Five and 10 per cent extracts of textured vegetable protein had substantial antioxidant activity, the higher concentration having more effect with longer storage. The vegetable extracts were less effective as antioxidants than textured vegetable protein alone. The combination of vegetables plus textured vegetable protein speeded lipid oxidation. Antioxidant activity was nearly the same for each concentration in vegetable-beef soup. Fatty acid changes in the beef in the soup, as determined by gas liquid chromatography, varied. Myristic and stearic acids remained more constant than palmitic, oleic, and linoleic acids.

5. Tatini, S.R., Stein, S.A. and Soo, H.M. 1976. Influence of protein supplements on growth of staphlococcus aureus and production of enterotoxins. J. Food Sci. 41:1, 133-135.

Abstract: Influences of soy protein (promine D; SP), fish protein concentrate (FPC) and Brewer's Yeast or Torula Yeast on aerobic growth of S. aureus (Z88) and production of enterotoxins A and D were evaluated in liquid media containing equivalent amounts (1.8%) of protein from each source. S. aureus grew faster (29 min generation time) and reached a final population of 27 X 10^9/ml in yeast media as compared to soy or fish protein concentrate; 50-56 min generation time and a final population of 2 X 10^8/ml in SP or FPC. Production of enterotoxins by S. aureus was enhanced in yeast media. Enterotoxin A was detectable in unconcentrated yeast preparations after 6 hr and both toxins (A and D) after 12 hr incubation. Enterotoxin A was detected only in FPC concentrated 50-fold and after 24 hr incubation. Neither enterotoxin A nor D was detected in SP concentrated 100-fold after 24- or 48-hr incubation. Addition of Brewer's Yeast (2% w/v) to whole milk enhanced production of enterotoxins A and D; there was at least a 100-fold higher amount of enterotoxin in milk + yeast as compared to simply milk.

IV. Oilseed Proteins

Oilseeds represent a very large potential source of texturized plant proteins. Although soybeans are in the oilseed class, they were covered separately in the preceding section (III) because of their dominance in the textured vegetable protein field and also because of the large amount of experimental work pertaining to soy and soy products.

Research on the remaining oilseeds perhaps has not advanced as fast as alternatives for soy, as earlier predicted. While much of the technology developed for the use of soy products such as the texturization process, is applicable to other oilseeds, each also has its unique characteristics, both economic and technical. Toxic and anti-nutrient constituents have caused processing difficulties. Factors such as gossypol, a problem in cottonseed, aflatoxins especially in peanuts, chlorogenic acid in sunflower, thioglucosides in rapeseed, as well as mycotoxins, indigestible fiber, and other phenolic compounds have to be removed to make other oilseeds competitive in the protein market. Soy also has had similar problems, but the long years of research on soy has resulted in a higher degree of sophisticated technology.

Today, however, many of the major problems in using other oilseeds have been overcome and these products are beginning to take their place in the market.

Oilseeds other than soy do have many positive attributes that make them attractive for use as textured plant proteins. Some may have a desirable amino acid balance, especially when used in combination with other proteins, the flavor may be more bland, the crop more plentiful, or the textural properties more desirable.

The references for oilseeds other than soy are grouped by type of oilseed. The first category contains references to papers with information on oilseeds in general or with applicability to more than one oilseed.

A. Oilseeds; general references

1. Bastiaens, F.G. 1976. Oilseed flour for human food. J. Am. Oil Chem Soc. 53:6, 310-315.

Abstract: Methods of producing oilseed flours, primarily soybean flours, for human consumption are reviewed. Differences between processing for human food and for animal feed are described.

2. Becker, W.B., and Tiernan, E.A. 1976. New technology in oilseed proteins. J. Am. Oil Chem. Soc. 53:6, 327-331.

Abstract: The protein industry is in a technical improvement revolution that will lead to tastier and flatulence-free products. They will have longer shelf life, allow higher product yields, and be more efficient in energy conservation. The improved processes discussed include methods for making superior quality flours and grits, better extruded products, and higher quality concentrates and isolates. The new products will have high protein efficiency ratio ratings and a broad range of nitrogen solubility index. Some of the decision-making information that processors should have before appropriating capital are described.

3. Beradi, L.C. 1976. Chemical properties of co-precipitated protein isolates from cottonseed, soybean and peanut flours. Presented at the 61st annual meeting of the American Association of Cereal Chemists, New Orleans, LA, Oct. 5-8, 1976.

Abstract: High protein, co-precipitated isolates were prepared in various combinations from cottonseed flour, soybean, and peanut flour (1:1, w:w). Proteins were extracted from each mixture with 0.034N NaOH (1:15, w:v). Each extract was acidified to pH2.5, adjusted to pH 5.0 and centrifuged. The recovered protein co-isolates were resuspended at neutral pH and lyophilized. Isolates were also made by directly precipitating the 0.034N NaOH extracts at pH 5.0, with or without subsequent neutralization. Chemical components, including protein and amino acids, of co-isolates and isolates that were resolubilized and adjusted to either pH 2.5, 5.0, or 7.0 reflected composition of the original flours and their mixtures. They had high protein (94+%) and low ash, lipid, and crude fiber content. Nitrogen solubilities ranged from 13 to 100% depending on pH. Gel electrophoresis of original extracts and isolates showed that protein dissociation occurs at acid pH, and reassociation follows as the pH is adjusted to 7.0. The co-isolates accounted for approximately 70% and 45% of the flour's nitrogen and weight, respectively. These cottonseed derivatives may be useful as new, low cost edible grade protein products for food formulations.

4. Cater, C.M., Rhee, C.R., Hagenmaier, R.D. and Mattil, K.F., 1974. Aqueous extraction - an alternative oilseed milling. J. Am. Oil Chem Soc. 51:4, 137—141.

Abstract: Oil can be removed from oilseed materials by a process which consists of an aqueous extraction of the comminuted seed, followed by a centrifugal separation which divides the aqueous extract into oil, solid, and aqueous phases. The protein may be recovered in the solid or aqueous phase, depending upon the conditions selected. Unit operations of this process are grinding, solid-liquid separation, centrifugation, demulsification, and drying of products. Aqueous extraction has been applied, to date, to coconuts and peanuts. For coconuts, a procedure has been developed to recover 93% of the oil and 91% of the protein. The major protein product is 25% protein and, when reconstituted in water, forms an acceptable beverage. The estimated production cost of this product is $.24/lb. For peanuts, the recovery of oil was 89% and protein 92% for the concentrate procedure, whereas the corresponding values for the isolate procedure were 86% and 89%, respectively. The costs of production were estimated as $0.17/lb of concentrate (67% protein) and $0.28/lb of isolate (89% protein). Aqueous extraction offers several advantages over conventional solvent extraction - less initial capital investments, safer operation, capability of discontinuous operation, and production of a variety of products. Another advantage of aqueous processing is the capability for utilization of certain chemicals to remove or inactivate undesirable substances. In the case of peanuts, hydrogen peroxide and sodium hypochlorite have proven to be effective for destruction of aflatoxins. Aqueous processing has the potential for application to a variety of other oilseeds.

5. Cegla, G.F., Meinke, W.W. and Mattil, K.F. 1976. Co and countercurrent multistage aqueous and aqueous:ethanol extraction of textured vegetable protein flours:process yields and process data. Presented at the 36th Annual Meeting of the Institute of Food Technologists, Anaheim, CA June 6-9, 1976.

Abstract: Co-and countercurrent multistage water and ethanol:water extraction of textured vegetable flours (soy and glandless cottonseed) have produced extracted TVPs with protein contents of 79 to 81% (moisture free basis). Extracted soy TVP samples are characterized by carbohydrate contents (NFE) of 14 to 15% and less than 3% ash. The extracted cottonseed flour TVP assayed around 7% ash and 8% NFE. Such results are achieved by both co-current and countercurrent extractions at 65°C with a ratio of extraction medium to original TVP to 6 to 1. Both a drain-press and a centrifugal approach were used to separate liquid extract from solids between extraction stages. The drain-press technique tends to favor higher protein content due to possible loss of insoluble carbohydrates and fiber to the extract. TVP solids losses to the extract ranged from essentially 30% for the cottonseed TVP to around 40% for the soy TVP. A countercurrent extraction is favored because a more concentrated extract is available for the recovery of solids. Dried extracted solids range from 21 to 36% protein, 9 to 13% ash and 57 to 69% NFE.

6. Cegla, G.F., Meinke, W.W. and Mattil, K.F. 1976. Composition and characteristics of aqueous extracted textured vegetable proteins: soy and cottonseed. Presented at the 36th annual meeting of the Institute of Food Technologists, Anaheim, CA June 6-9, 1976.

Abstract: Amino acid composition and other characteristics of extracted textured vegetable protein flours, made from soy and cottonseed, were determined. The amino acid profiles for original and extracted products were essentially the same. Only Lysine content was lower by approximately 10% in the extracted samples. The extracted extrudates had a greater textured integrity, water absorption capacity and water holding capacity than the original TVP. However, the converse was found for the oil emulsification capacity of the same materials. Bulk densities of the extracted products compared with the original materials, were significantly lower for the soy, but higher for the cottonseed. Meat patties prepared with the extracted TVP samples were organoleptically superior to patties prepared from a commercial soy concentrate and were judged equal to patties prepared from the original unextracted extrusion textured soy and cottonseed flours.

7. Conkerton, E.J. 1974. Gas chromatographic analysis of amino acids in oilseed meals. J. Agric. Food Chem 22:6, 1046-1051.

Abstract: The amino acid contents of a soybean and a peanut meal were determined by the classical ion-exchange procedure and by gas chromatography. After derivatizing the amino acids as their N-trifluoroacetyl n-Butyl esters, gas chromatographic analysis yielded reproducible quantitative data for all of the common protein amino acids except tyrosine, arginine, and histidine. Statistical analysis of the data indicated that gas chromatographic analysis gives results comparable to those obtained by ion-exchange chromatography. Some advantages and disadvantages of the gas chromatographic method are discussed.

8. Crenwelge, D.D., Dill, C.W., Tybor, P.T. and Landmann, W.A. 1974. A comparison of the emulsification capabilities of some protein concentrates. J. Food Sci. 39:1, 175-177.

Abstract: The emulsification capacities of four proteins were compared under experimental conditions optimized for blendor speed, pH, rate of oil addition and protein concentration. The emulsification capacity (oil phase volume at inversion) for the four proteins indicated that all were good emulsifiers. The amounts of protein required to obtain maximum oil phase volume differed between samples. The amounts of each protein required for this maximum effect were approximately 0.40% for globin, 0.88% for cottonseed protein, 0.98% for soy protein and 1.19% for milk proteins, all expressed as a percentage of the aqueous phase. The emulsification capacity for each protein related closely to the concentration of soluble protein in the sample.

9. Dieckert, J.W., Dieckert, M.C. 1976. The chemistry and cell biology of the vacuolar proteins of seeds. J. Food Sci. 41:3, 475-482.

Abstract: Ultrastructural, cytochemical and immunochemical evidence obtained using different plant families supports a suggested model for the biosynthesis of the storage proteins of seeds. Aleurones of the legumin type are proposed to be homologous. The proposed homologues are usually hexamers or tetramers of a disulfide bridged subunit of the A-S-S-B type. The large observed variations in amino acid composition of the proposed homologues imply they are liberal proteins; i.e., large variations in the amino acid sequence of the subunits do not cause lethal effects nor change the function of the protein. The list of proposed legumin homologues includes the legumins, glycinin, arachin, edestin and cocosin. Some unnamed cottonseed proteins also seem to qualify.

10. Fleming, S.E., Sosulski, F.W., Kilara, A., and Humbert, E.S. 1974. Viscosity and water absorption characteristics of slurries of sunflower and soybean flours, concentrates and isolates. J. Food Sci. 39:1, 188-191.

Abstract: The viscosity and water absorption characteristics of slurries of sunflower flours, concentrates and isolates were compared with soy flours, concentrates and isolates. The commercial soy isolate showed higher water absorptions and higher viscosities at each concentration than the soy flour and concentrate while the sunflower concentrates were much more viscous and generally had higher water absorptions than the other sunflower products. The soy flour slurries were more viscous than sunflower flour, whereas the sunflower concentrates were substantially more viscous than the corresponding soy product. The soy isolates showed viscosities much higher than the sunflower isolates. In addition, the slurries of sunflower and soy concentrates which were cycled through the pH treatment had viscosities similar to those of the soy isolates. The viscoamylograph curve demonstrated that the soy isolate had a high peak and cold viscosity, while concentrates from sunflower showed no peak but very high cold viscosities. By varying the temperature, mixing regime, slurry medium and slurry concentration, and by pH-activation, a product can be altered to produce a wide variety of water absorption and viscosity characteristics. The results should be correlated with their functions in such food systems as beverages, gravies, sauces, and meat products.

11. Lawhon, J.T., Mulsow, D., Cater, C.M. and Mattil, K.F. 1976. Production of protein isolates and concentrates from oilseed flour extracts using industrial ultrafiltration and reverse osmosis systems. Presented at the 36th annual meeting of the Institute of Food Technologists. Anaheim, CA June 6 - 9, 1976.

Abstract: The consumption of protein isolates from oilseed flours is expected to continue its upward trend as meat analogs from vegetable proteins are more widely marketed. However, conventional protein isolation procedures are lengthy and somewhat expensive. These processes also result in whey-like

liquid by-products which constitute a water pollution threat unless properly processed. Preparation of protein isolates and concentrates from glandless cottonseed and soy flours by extracting the protein and ultrafiltering the solubilized protein directly from the liquid extract was investigated. In the process devised, proteins normally precipitated to produce isolates were recovered with the conventional whey protein by ultrafiltration (UF). The UF permeate was further processed with a reverse osmosis (RO) membrane. Different industrial UF and RO systems were utilized in 22-to 60-pound extractions. UF membranes were found which gave desirably high permeation rates and satisfactory constituent separations, especially with cottonseed storage protein (SP) extract. With SP extract, initial UF permeate flux achieved was in excess of 150 gfd. The flux declined to 96 gfd over a period of eight hours while the volume of original extract in the feed solution was being reduced by a ratio of 12.5 to 1 in the final UF concentrate. As expected, non-storage protein (NSP) and SP extracts from cottonseed were found to require membranes having different molecular weight cutoff points. Non-cellulose-based membranes performed better for this application because of their broader pH and temperature operating ranges.

12. Meyer, E.N.W. 1974. Oilseed protein concentrates and isolates. J. Am. Oil Chem. Soc. 51:1.

Abstract: Much attention has been focused on the oilseed crops as an alternate and largely untapped source of food protein in an endeavor to provide needed nourishment for large segments of the world's expanding population. A significant part of this attention has been devoted to the practical concentration and isolation of the proteins of several oilseeds. As a result of intensive effort during the last decade, soy protein concentrates and isolates are now commercial commodities which are gaining increasing acceptance as useful functional and nutritional ingredients for food. This report is concerned with a brief review of the commercial processing, product characteristics, and food utilization of soy protein concentrates and isolates. In addition, pertinent comments on the concentrates and isolates of other oilseed are included.

B. Coconut Proteins

Coconuts as a source of protein are being evaluated using both the coconut milk and the coconut meal. An advantage of coconut use is that it does not contain known toxic substances which are found in other oilseeds. However, indigestible fiber must be extracted from the coconut flour.

1. Gunetileke, K.G. and Laurentius, S.F. 1974. Conditions for the separation of oil and protein from coconut milk emulsion. J. Food Sci. 39:2, 230-233.

Abstract: Coconut milk extracted from fresh coconuts was centrifuged to obtain cream and skim milk. The whole mass of cream was chilled to 17°C or below. It was established that 17°C was the critical temperature for subsequent phase separation. At 17°C crystallization of the oil phase was observed under the microscope. On warming to 25°C the emulsion broke with separation of oil and protein. This process differs from similar processes in that no enzymes are used and the temperature of the whole mass of cream has to be lowered only to 17°C. The oil obtained did not differ significantly from commercially available oil. Amino acid composition of different protein fractions was determined.

2. Hagenmarer, R.D., Quanitio, P.H., and Clark, S.P. 1975. Coconut flour: technology and cost of manufacture. J. Am. Oil Chem. Soc. 52:11, 439-443.

Abstract: Processing operations are described for production of oil and coconut flour from fresh coconuts. The nuts first are made into white desiccated coconuts in drying plants, and the prepressed, flaked, and hexane extracted in a central facility. White coconut flour that is produced contains 25% protein and only 0.5% oil. The process would be commercially feasible in the Philippines if a coconut flour price of $315 per metric ton were assumed. Current commercial production of coconut flour is zero. However, coconut flour has good nutritive value; contains no known substances present at toxic levels as do some other oilseeds.

3. Lachance, P.A. and Molina, M.R. 1974. Nutritive value of a fiber-free coconut protein extract obtained by an enzymic-chemical method. J. Food Sci. 39:3, 581-584.

Abstract: The fiber-free coconut extract obtained by an enzymic-chemical method (J. Food Sci. 38:4, 607) proved to have a higher protein nutritive value than that of the original coconut meal. The improvement is attributable in part to the fact that the fiber of unmodified coconut meal has an unfavorable effect on the nutritive value of coconut protein. Amino acid analysis revealed that the extracted protein had a higher total essential amino acid content including a higher lysine content and a higher lysine-to-arginine ratio than the original coconut meal.

4. Molina, M.R., Lachance, P.A. and Bressani, R. 1976. Some chemical and functional characteristics of a fiber-free coconut protein extract obtained by the enzymatic chemical process. J. Agri. Food Chem 24:3, 614-617.

Abstract: The coconut protein extract obtained through the enzymic chemical process contained 32.4% protein and 42.6% of nitrogen-free extract. It also had a high total sugar content (39.2%) and a relatively small amount of reducing sugars (6.2%). Hydrolysis and paper chromatography were used to determine the composition of the total sugars. Column chromatography showed that 66% of the protein had a molecular weight higher than 5000. Only 41.3% of the protein proved to be nondialyzable, suggesting a molecular weight higher than 12000. Such a protein fraction was electrophoretically homogeneous. The protein showed minimum solubility at pH 7.0 and 34.2% was heat coagulable at 120°C. The extracted product was highly dispersible with an emulsifying capacity of 24.8 ml/g and did not form a gel at 15 and 30% levels. Preliminary tests showed possible practical applications of the extracted product in drinks and bakery products' formulations.

5. Molina, M.R. and Lachance, P.A. 1973. Studies on the utilization of coconut meal. A new enzymatic-chemical method for fiber free extraction of defatted coconut flour. J. Food Sci. 38:4, 607-610.

Abstract: A simple enzymic-chemical protein extraction process was developed. Proteases rather than carbohydrases were more efficient for the enzymatic treatment. Dilute NaOH was more effective than dilute HCl for the complementary chemical treatment. The combined treatments were more efficient than each of the two separately. The method devised was equally effective when applied to five coconut meals obtained through different oil extraction techniques. The partial hydrolysis of the protein during the proteolytic enzyme treatment appears to enhance the protein extractability by the complementary chemical treatment. Further, the resultant product is free of fiber.

C. Cottonseed Proteins

The potential of using cottonseed meal as a protein extender is mentioned quite often in the literature. The removal of the gossypol has been the main focus of research. To alleviate the problem of gossypol two main areas are being explored. The first uses chemical treatment, extracting the gossypol with hexane in a liquid cyclone process and the second method is gentically removing the gossypol by producing glandless cottonseed.

The abstracts and summaries listed under cottonseed may at times seem confusing regarding the actual production of edible cottonseed flour. This is because an operation was established in 1974 in Texas to commercially produce food grade cottonseed. However, this producer has discontinued processing and there is no commercial production of food grade cottonseed in the United States at this time.

1. Childs, E.A. 1975. An enzymatic chemical extraction method for cottonseed protein. J. Food Sci. 40:1, 78-80.

Abstract: Experiments were undertaken to improve the extraction of protein from heat-treated cottonseed meal by treating the meal with proteolytic enzymes. A two-stage chemical technique (water and 0.075% NaOH) extracted approximately 15% of the cottonseed meal protein. Papain treatment did not markedly increase the amount of protein extracted but trypsin treatment increased protein extraction fivefold. The increased efficiency of trypsin resulted from the increased amounts of protein extracted in the NaOH fraction. Greater than 50% of cottonseed protein could be extracted from meal held at 204°C for 30 min.

2. Childs, E.A. and Forti, J.F. 1976. Enzymatic and ultrasonic techniques for solublization of protein from heat-treated cottonseed products. J. Food Sci. 41:3, 652-655.

Abstract: Extraction of protein from cottonseed meal was fourfold more efficient when the meal was treated with trypsin than when treated with ultrasonic energy. Combination of the two techniques caused efficient protein extraction with low expenditures of time, enzyme and energy. The extracted proteins bound $>$ 3.5 ml oil/g concentrate and $>$ 2.4g water/g concentrate and emulsified $>$ 325 ml oil/g concentrate.

3. Childs, E.A. and Park, K.K. 1976. Functional properties of acylated glandless cottonseed flour. J. Food Sci. 41:3, 713-714.

Abstract: Glandless cottonseed flour was acylated with succinic and acetic anhydride. Acylation caused an increase in the specific viscosity of the flour and an increase in its functionality. Water-holding, oil-holding, emulsifying and foam capacities were increased from 1.2 to tenfold over non-acylated flour.

4. Harden, M.L. and Yang, S.P. 1975. Protein quality and supplementary value of cottonseed flour. J. Food Sci. 40:7, 75-77.

Abstract: Amino acid analyses and rat growth studies were used to determine the quality of proteins in glanded, glandless, and liquid cyclone processed (LCP) cottonseed flours using casein and soybean oil meal as references. The cottonseed proteins contained approximately the same amount of methionine and threonine but slightly less lysine as compared to soybean and casein. The greatest deviation in net protein utilization (NPU) for all diets occurred at the 10% protein level, while NPU values varied slightly at 20% protein levels. Young rats fed the glanded cottonseed flour died within 5 days. When LCP and glandless cottonseed flours were substituted for 18.8% of wheat flour in a yeast bread, the protein content increased from 10.48% to 19.06% and 21.13%, respectively. Amino acid data and NPU value showed that LCP and glandless cottonseed flours made significant improvement to the nutritive value of a wheat flour yeast bread.

5. Herzer, J.F. 1973. Bright future for cottonseed flour - a comment. Food Engineering 45:11, 131.

Summary: Development of the cottonseed market has been hampered by governmental regulations and the short supply of liquid cyclone protein concentrate. When available, the Grain Processing Company will refine the process in their pilot plant and subsequently develop their market for its use.

6. Johnson, J., Alford, B.B. and Pyke, R.E. 1975. Guidelines for preliminary food formulations using cottonseed products. Food Product Development 9:4, 40-42.

Summary: Reported use of cottonseed proteins in human foods as extenders is limited to frankfurts and meat loaves. The flavor of cottonseed flour, meat or tamunuts (toasted cottonseed kernels) did not detract from flavors of animal protein foods — meat, cheese and eggs. Cottonseed flour products were added to ground beef, pork, and lamb as extenders at levels up to 50% by weight before acceptability lessened appreciably.

7. Kokoczka, P.J. and Stevenson, K.E. 1976. Effect of cottonseed and soy products on the growth of _Clostridium perfringens_. J. Food Sci. 41:6, 1360-1362.

Abstract: The objective of this research was to investigate the effect of cottonseed and soy products on the growth of _Clostridium perfringens_. Cultures of _C. perfringens_ were inoculated into liquid media and enumerated on egg yolk-free tryptose-sulfite-cycloscrine agar. In autoclaved media containing cottonseed or soy products as the sole source of protein, there were no significant differences in generation times due to the protein sources. However, a significant difference ($p < 0.001$) was observed between the generation times of _C. perfringens_ strains ATCC 3624 and NCTC 8238. In another series of experiments,

C. perfringens ATCC 3624 was grown in autoclaved media containing ground beef, chicken or turkey, alone or in combination with cottonseed and soy products. The substitution of one-half of the meat protein with cottonseed protein resulted in significant increases in generation times (decreases in growth rates) when compared to meat alone. Also, the carbohydrate fractions of cottonseed products retarded the growth of C. perfringens. Substitution with soy protein did not significantly affect the generation times. The results of this investigation show that cooked cottonseed and soy products added to meat systems have a variable effect on the growth of C. perfringens.

8. Lawhon, J.T., Lin, C.H.C., Rooney, L.W., Cater, C.M., and Mattil, K.F. 1974. Utilization of cottonseed whey protein concentrates produced by ultrafiltration. J. Food Sci. 39:1, 183-187.

Abstract: Whey type liquid by-products from the manufacture of protein isolates from glandless cottonseed flour were processed with semipermeable ultrafiltration (UF) membranes to fractionate and concentrate whey constituents before spray drying. Three different cottonseed wheys resulting from two isolation procedures were processed. The three spray-dried protein products obtained were evaluated for potential use in protein fortification of breads or noncarbonated beverages, and also as whipping products. Separation of carbohydrates and salts (though incomplete) from protein by the UF membrane yielded light cream colored protein-rich products greatly enhanced in whippability and in their utility for beverage fortification over that of unfractionated whey solids. Membrane fractionation significantly increased most of the essential amino acids. Available lysine in the products was increased by more than 50% of the available lysine of the original flour.

9. Lin, C.H.C., Lawhon, J.T., Cater, C.M., and Mattil, K.F. 1974. Composition and characteristics of glandless and liquid cyclone processed deglanded cottonseed wheys. J. Food Sci. 39:1, 178-182.

Abstract: Cottonseed wheys are liquid by-products from cottonseed protein isolation processes. These wheys when prepared in the laboratory contained 22-36% of the original flour solids or 12-23% of the flour nitrogen. Differences among various wheys from different processes were clearly indicated by their chemical compositions and gel filtra-contained up to 7% lysine and 5% cystine. Whey carbohydrates were mainly raffinose and sucrose. Minerals and vitamins in cottonseed wheys were also shown for comparison. Recovery of the utilizable whey constituents to minimize disposal problem was emphasized.

10. Mayorga, H., Gonzalez, J., Menchu, J.F. and Rolz, C. 1975. Preparation of a low free gossypol cottonseed flour by dry and continuous processing. J. Food Sci. 40:6, 1270-1274.

Abstract: A method was devised whereby a combined treatment of chemical additives and dry heat was used to reduce the free gossypol levels of

commercial cottonseed cakes without altering their original protein quality. Laboratory trials were done first where around 60% of the initial free gossypol was destroyed by the combined treatment. A pilot plant set up was designed, constructed and operated with different type of meals. The system gave comparable results when operated with prepress solvent meal and the temperature held between 150–190°C. The products were tested in two 9-week feeding trials with laying hens, incorporating up to 15% of the final formula. The results obtained were satisfactory as no discoloration was found in the yolk even after 3 months cold storage at 6°C. The controls in which high gossypol cake was employed induced darkening of the yolk.

11. Ridlehuber, J.M. and Gardner, H.K., Jr. 1974. Production of food-grade cottonseed protein by the liquid cyclone process. J. Am. Oil Chem. Soc. 51:4, 153–157.

Abstract: A brief background is presented on the development of the liquid cyclone process as modified to process glanded cottonseed kernels from the Texas high plains into a gland-free 65+% protein flour. Southern Regional Research Center's pilot plant process is described and related to the commercial process that will become operational in early 1974 at Plains Cooperative Oil Mill, Lubbock, Texas. Some of the functional properties of the flours and results of their evaluation in food application are discussed.

12. Molonan, B.R. and Bowers, J.A. 1976. Sensory evaluation and protein value of beef and beef-cottonseed blends. J. Food Sci. 4:6.

Abstract: Textured cottonseed flour (TCF) was added to ground beef at levels of 0, 15 and 30%. Effects on chemical and sensory properties were determined by compositional analysis and sensory evaluation of cooked beef patties. Protein quality was evaluated by rat feeding studies. Although cooking losses and cooking time, moisture and protein contents were unaffected by TCF, fat content was greater for 100% beef patties, and, Gardner redness values decreased while yellowness increased with increased TCF. Increasing TCF decreased beef flavor and aroma and increased cereal flavor and aroma. Texture, similar for 100 or 85% beef patties, was mealier for patties containing 70% beef, and 100% beef patties were juicier. Growth (measured by protein efficiency ratios) was supported at a higher rate by beef blends than by casein, and net protein ratios, similar for 100 or 85% beef blends, were lower for the 70% blend. Digestibility of all treatments was excellent.

13. Taranto, M.V., Meinke, W.W., Cater, C.M. and Mattil, K.F. 1975. Parameters affecting production and character of extrusion texturized defatted glandless cottonseed meal. J. Food Sci. 40:6, 1264–1269.

Abstract: The product characteristics examined were found to be influenced by the process temperature, feed rate and screw speed. At a constant screw speed of 650 rpm, a maximum product temperature can be achieved by

operating the Wenger X-5 at a feed rate of 136 g/min and a process temperature of at least 135°C. At a constant feed rate of 136 g/min, a maximum product temperature can be achieved by operating the Wenger X-5 at a screw speed of 650 rpm and a process temperature of at least 135°C. The most homogeneous product was produced at 650 rpm and 1.36 g/min. Increasing the screw speed at a constant feed rate of 136 g/min caused an increase in the percent water regain, diameter and adjusted shear stress and a decrease in the density of the extrudate. Interaction between screw speed and process temperature was indicated, but not substantiated by statistical analysis. Fibers formed during the extrusion process are stronger when produced at the higher screw speeds (650-900 rpm). At 900 rpm and 136 g/min, increasing the process temperature above 135°C causes a disruption of the extrudate's structure as indicated by a decrease in the adjusted shear stress. The glanded flour was the only product that did not exhibit phytase activity. The amount of inorganic phosphate released by the glandless air-classified flour during enzyme activity was significantly higher (1% level) than the amounts released by either the glandless flour or the toasted kernels.

14. Wozenski, J. and Woodburn, M. 1975. Phytic acid and phytase activity in four cottonseed protein products. Am. Chem. 52:5, 665-669.

Abstract: Phytic acid, as myoinositol hexaphosphate (g/100g), found in each product as received was 2.86 in a glanded flour, 4.29 in a glandless flour, 3.35 in an air-classified glandless flour, and 2.49 in toasted seed kernels. The glandless flour was significantly higher in phytic acid than the glanded flour (5% level) and than the seed kernels (1% level). On a defatted basis, the glanded flour had a much lower level of phytic acid than the other products.

15. Ziemba, J.V. 1973. First cottonseed protein plant now on-stream. Food Eng. 45:11, 124-131.

Summary: Food-grade cottonseed protein with excellent nutritive and functional properties will soon be produced commercially. The plant is designed to produce 25 tons of a 65% protein flour in 24 hours and could produce 50 tons. They will use a continuous liquid cyclone processing system developed at the USDA's Southern Regional Research Center. Initially the flour will be used for fortification. The most important part of the operation is separation into two cyclones. Hexane is used as a solvent and the hexane-cottonseed slurry is pumped at 40 psi into each cyclone to give a swirling action which fractionates into three portions: flour (top), gossypol (center) and residue (bottom). A flowsheet shows the operational steps.

16. Cottonseed protein nears commercial production. 1973. Food Processing 34:4 F25.

Summary: The liquid cyclone process method for removing gossypol will be used commercially in 1973 or 1974 in the production of deglanded cottonseed flour. The flour contains 65% protein, is cream in color and bland in flavor.

Other cottonseed protein products will soon be available. The isolates will fall into two groups: one expected to find application in baked goods; the other, relatively low in lysine and the sulfur amino acids, texturizes when heated and is acid soluble.

17. High protein foods from cottonseed. 1971. Food Processing 32:4 F4-F6.

Summary: A recent processing breakthrough permitting the economical removal of gossypol from cottonseed can herald the commercial production of high protein products made from cottonseed. The liquid cyclone process removes the pigment glands and lipids and concentrates the protein. The procedure starts by drying the meats, passing them through flaking rolls and then fluidizing them with hexane. The fluidized slurry is comminuted in a stone mill and the solids content adjusted for the proper separation of the flour from glands, hulls and coarse meal in the cyclone. The flour is filtered, defatted with hexane and desolventized.

D. Peanut protein

It is commonly believed that peanut protein will be the first protein alternative to soy. Peanut flakes containing from 29.4% protein (full fatted) to 58.7% protein (defatted) are now commercially produced. The removal of aflatoxins has been a matter of concern in processing peanuts.

1. Ayres, J.L., Branscomb, L.L. and Rogers, G.M. 1974. Processing of edible peanut flour and grits. J. Am. Oil Chem. Soc. 51:4, 133-136.

Abstract: Edible peanut flour and grits have been produced by a commercial prepress solvent extraction method. The finished flour exhibits excellent extrusion-expansion characteristics for use in both cereal and snack food items. Soluble carbohydrate profile indicates peanut flour is lower in raffinose and stachyose than commercial soy flour. The bland flavor and light tan color facilitates incorporation of peanut flour and grits into a wide range of food products. Extruded peanut flour when placed in water has very little structural identity. However, soy and peanut blends showed superior flavor over soy alone in extended, ground beef patties.

2. Basha, S.M.M., and Cherry, J.P. 1976. Composition, solubility and gel electrophoretic properties of proteins isolated from Florunner (Arachis hypogaea L.) Peanut seeds. J. Agric. Food Chem. 24:2, 359-367.

Abstract: Defatted peanut (Arachis hypogaea L.) meal was homogenized with various extraction media to determine optimum conditions for qualitative and quantitative recovery of proteins. Maximum recovery of both arachin and nonarachin proteins was accomplished with 1 M NaCl-20 mM sodium phosphate buffer (pH 7.0). Other extraction media compared and found to be less efficient in recovering soluble seed proteins were 10% NaCl, sodium phosphate buffer (pH 7.9, I=0.03), and water. A method was developed to prepare relatively pure isolates of arachin and nonarachin proteins from the total soluble fraction extracted with 1 M NaCl-20 mM sodium phosphate buffer using a series of simple steps involving differential solubility, cryoprecipitation, and dialysis; the degree of purity of these isolates was determined by "standard" polyacrylamide disc gel electrophoretic techniques. Gel electrophoresis of sodium dodecyl sulfate dissociated proteins showed these isolates each contained five different components having molecular weights between 20000 and 84000. In addition, the arachin and nonarachin components were found to be glycoproteins containing both neutral and amino sugars. These isolates differed in amino acid composition, e.g., nonarachin proteins contained approximately twice as much serine (7.5 g/100g of protein), half-cystine (2.7), methionine (2.0), and lysine (5.6) compared to arachin.

3. Beuchat, L.R., Cherry, J.P. and Quinn, M.R. 1975. Physio-chemical properties of peanut flour as affected by proteolysis. J. Agric Food Chem. 23:4, 616-620.

Abstract: Defatted peanut flour was hydrolyzed with pepsin, bromelain, and trypsin. Nitrogen solubility was increased substantially in water at pH 4.0-5.0 and in 0.03 M Ca^{2+} at pH 4.0-11.0. Water adsorption by the flour when exposed to various relative humidities was increased as a result of hydrolysis. Emulsion capacities in water and in 0.5 M NaCl were completely destroyed during digestion and water and oil-retaining properties were reduced when compared to control samples. Gel electrophoretic patterns showed substantial qualitative changes in enzyme-treated peanut protein. Patterns were different for each of the hydrolysis treatments.

4. Cherry, J.P., McWatters, K.H. and Holmes, M.R. 1975. Effect of moist heat or solubility and structural components of peanut products. J. Food Sci. 40:6, 1199-1204.

Abstract: Gel electrophoretic analyses were conducted to specifically evaluate the sequence of changes in solubility and structural components of proteins in peanuts subjected to moist heat. Heating conditions included temperatures ranging from 50°C to 120°C and time intervals of 15 to 210 min. Temperatures of 100°C and 120°C were used to decrease markedly the amount of soluble protein. However, extended heating at 120°C increased the proportion of soluble proteins. Heated peanuts stored for different time intervals (i.e., holding times which included frozen immediately, stored overnight, or stored overnight and ground) prior to lyophilization showed protein solubilities which varied among treatments: t-values testing this variability showed that much of it was not significant. Polyacrylamide gel electrophoresis showed only minor qualitative changes in proteins of peanuts heated at 50°C or 75°C. However, in gel patterns of peanuts heated for 15 to 75 minutes at 100°C, it became increasingly difficult to detect nonarachin proteins. Simultaneously, a new group of protein bands was formed in these gel patterns during this heating period. When heating was extended beyond 105 minutes at 100°C, arachin (major storage globulin of peanuts) became less defined in the gel patterns and was not present in the soluble fraction of seeds after heating them for 210 minutes. The prolonged heating resulted in further new components detectable by gel electrophoresis. At 120°C, similar changes were observed between 15 and 90 minutes. A broad diffuse band of intermediate migration was prevalent in gels of peanuts heated at 120°C for 105 to 210 minutes. Although moist heat at high temperatures denatured the proteins, many of the new structural components remained soluble even after peanuts were heated at 120°C for 210 minutes. A multiple regression analysis indicated that approximately 90% of the variability in the solubility of proteins from heated peanuts could be explained by a model that included the various heat treatments.

5. Codifer, L.P., Mann, G.E., and Dollear, F.G. 1976. Aflatoxin inactivation: treatment of peanut meal with formaldehyde and calcium hydroxide. J. Am. Oil Chem. Assoc. 53:5, 204-206.

Abstract: A peanut meal contaminated with ca. 600 ppb aflatoxins was

treated with formaldehyde alone and in combination with calcium hydroxide in a bench-scale reactor, operated both sealed and at atmospheric pressure. In general, thin layer chromatographic assays revealed that addition of calcium hydroxide to formaldehyde caused greater inactivation of the toxins than did formaldehyde alone. With the reactor sealed and 25% moisture in the meal, treatments for 1 hr with 0.5% and 1.0% formaldehyde plus 2.0% calcium hydroxide yielded products having 3 and 1 ppb aflatoxins, respectively, whereas under reflux at atmospheric pressure with 20% meal moisture, 1 hr treatment with 1.0% calcium hydroxide yielded a product with 5 ppb aflatoxins.

6. McWatters, K.H., and Cherry, J.P. 1975. Functional properties of peanut paste as affected by moist heat treatment of full-fat peanuts. J. Food Sci. 40:6, 1205-1209.

Abstract: Full-fat peanuts were heated at 50, 75, 100 and 120°C for 15-min intervals ranging from 15 to 180 minutes. Treated samples were ground into paste and evaluated for protein content, moisture uptake, emulsion capacity and viscosity, foaming capacity, and firmness. Moisture uptake increased as time and temperature of heating increased. Peanuts heated at 50, 75 or 100°C for 15 to 90 minutes exhibited good emulsifying properties. Further heating at 100°C reduced emulsification capacity, and no emulsions could be formed beyond 15 min at 120°C; for this reason, further analyses of functional properties were not conducted under these latter conditions. Emulsions of all heat-treated samples were less viscous than the unheated control. Foaming capacity increased as heating temperature was raised from 50°C to 100°C. Foams prepared from peanuts heated at 75°C and 100°C were more stable than those receiving mild heat (50°C). Paste firmness decreased as heating time and temperature increased. Multiple regression analyses of samples heated at 50°C to 100°C for time intervals of 15 to 90 minutes showed interaction of moist heat treatments and functional properties to be very complex. Time and temperature treatments were the most significant factors affecting functional properties. Soluble protein variation had only a secondary effect on the functionality of moist-heated products. However, the data suggest that specific proteins as well as other constituents in the seeds have a marked effect on functional properties.

7. McWatters, K.H., Cherry, J.P. and Holmes, M.R. 1976. Influence of suspension medium and pH on functional and protein properties of defatted peanut meal. J. Agri. Food Chem. 24:3, 517-523.

Abstract: Defatted peanut (*Arachis Hypogaea* L. C.V. Florunner) meal was blended with either water, 0.1 M NaCl, or 1.0 M NaCl and the pH of each suspension adjusted to either 1.5, 4.0, 6.7, or 8.2; two-step sequential adjustments from 6.7 to 4.0 to 6.7 and from 6.7 to 4.0 to 8.2 were also included. All suspensions had similar viscosities. Those at pH 4.0 produced soluble extracts with lowest percentage protein and failed to form emulsions. Suspensions at pH 6.7 varied widely in percentage protein, produced the least increase in foam volume, and formed poor emulsions. The most desirable emulsions and foams were

produced by peanut meal-water suspensions adjusted from pH 6.7 to 4.0 to 8.2 and from pH 6.7 to 1.5. Gel electrophoresis of soluble proteins and multiple regression analysis showed that functionality of peanut meal was influenced by complex interactions involving suspension medium, pH, and level and character of soluble proteins.

8. McWatters, K.H. and Heaton, E.K. 1974. Influence of moist-heat treatments of peanuts on peanut paste characteristics. J. Food Sci. 39:3, 494-497.

Abstract: Further information on the effects of moist heat on certain qualitites of peanuts was obtained by heating skin-free kernels in water at 90, 120, 150, 180 and 210°F for 15, 30, 45, 60, 75 and 90 min. They were drained, held overnight and ground into paste, and evaluated for moisture uptake, shear resistance, color, grinding characteristics and flavor. The performance of peanut paste in a food system was determined by substituting it for almond paste in a macaroon cookie formula. Results showed that moisture uptake and L and b color values increased as the heating temperature and time increased. Resistance to shear decreased as heating time increased for samples heated at 150, 180 and 210°F. At 90 and 120°F, however, there were irregular patterns of moisture uptake and shear resistance. All samples were easily ground in a stone mill except those heated at 120°F for 75 and 90 minutes which were sticky and gummy. Sensory evaluation indicated that the peanut flavor of the paste was improved by heating at temperatures of 180 and 210°F. Both heating time and temperature affected the consistency and handling of macaroon cookie batters prepared from the paste as well as the sensory qualities of the finished products. Cookies having the highest overall quality were obtained from pastes with a moisture content of 23-27% and heat treatments of 30 or 45 min at 180°F or 15 min at 210°F.

9. Natarajan, K.R. 1975. Destruction of aflatoxins in peanut protein isolates by sodium hypochlorite. J. Am. Oil Chem. Soc 52:5, 160-163.

Abstract: Sodium hypochlorite has been tested for destruction of aflatoxins during the preparation of peanut protein isolates from raw peanuts and defatted peanut meal. The treatments were evaluated by determination of the aflatoxins in the products by thin layer chromatography. Effects of sodium hypochlorite concentration, reaction pH, temperature, and time were studied. Results show that both the sodium hypochlorite concentration and pH are important factors in reducing the concentration of aflatoxins in the protein isolates to nondetectable levels. The treatment with 0.4% sodium hypochlorite at pH 8 produced protein isolates with trace amounts of aflatoxins B_1 and B_2 from ground raw peanuts containing 725 ppb aflatoxin B_1 and 148 ppb aflatoxin B_2, whereas untreated protein isolates contained 384 ppb aflatoxin B_1 and 76 ppb aflatoxin B_2. At pH 9, 0.3% sodium hypochlorite reduced the aflatoxin B_1 content in the protein isolates from 300 ppb to below detectable quantities and the aflatoxin B_2 content from 52 ppb to 2 ppb. Similar results were obtained at pH 10 for 0.3% sodium hypochlorite concentration. In the case of defatted peanut meal which contained

136 ppb aflatoxin B_1 and 36 ppb aflatoxin B_2, 0.25% sodium hypochlorite concentration of pH 8 (0.20% at pH 9; 0.15% at pH 10) reduced both the aflatoxin B_1 and B_2 contents to below detectable quantities in protein isolates as compared to aflatoxin levels of ca. 75 ppb B_1 and 17 ppb B_2 in the untreated protein isolates. Reaction temperature and time did not affect the destruction of aflatoxins significantly.

10. Natarajan, K. R., Rhee, K.C., Cater, C.M. and Mattil, K.F. 1975. Distribution of aflatoxins in various fractions separated from raw peanuts and defatted peanut meal. J. Am. Oil Chem. Soc. 52:2, 44-47.

Abstract: The present investigation is the first definitive study of the distribution of aflatoxins in a wet-milling process of raw peanuts. The results show that the majority of the aflatoxins originally present in the peanuts remained in the solid fractions, particularly the protein fraction, during wet-milling. In the protein concentrate preparation, the concentrates carried 81-89% of the total toxin; crude oil, 5-8%; and whey fraction, 3-14%. In the case of protein isolate preparation, 51-56% of the total toxin remained with the isolates, 22-26% with the residue, 11-17% with the whey, and 7-8% with the crude oil. Distribution of aflatoxins in the preparation of protein isolates from defatted peanut meal showed that 55-65% of the total toxin originally present in the meal remained with the protein isolates, 20-28% with the residue, and 10-20% with the whey fraction. Changes in extraction pHs for the preparation of protein isolates either from raw peanuts or defatted meal did not alter the distribution pattern mentioned above. A new approach based upon charge-transfer (electron acceptor-donor) complex formation is suggested to shift this aflatoxin distribution from protein products to disposable whey or residue fraction during the processing of raw peanuts and defatted meal for protein products.

11. Natarajan, K.R., Rhee, K.C., Cater, C.M. and Mattil, K.F. 1975. Effect of sodium hypochlorite of peanut protein isolates. J. Food Sci. 40:6, 1193-1198.

Abstract: The effect of sodium hypochlorite on the color, viscosity, solubility and amino acid composition of peanut protein isolates prepared under different pH conditions was investigated. Results were compared with those of protein isolates prepared without sodium hypochlorite treatment. By visual observation, untreated protein isolates are lighter in color than the sodium hypochlorite-treated protein isolates which appeared somewhat beige. The solution viscosities of treated isolates measured at neutral pH were slightly less than those of untreated isolates. The solubility profiles showed that both treated and untreated protein isolates were quite soluble at pH's below 3 and above 7.5. The sodium hypochlorite-treated isolates were relatively less soluble in the pH range 5.5-7.5. Except for tyrosine and tryptophan, there were no significant differences in the amino acid composition between treated and untreated protein isolates. Polyacrylamide gel electrophoresis in the presence of sodium dodecyl sulfate revealed specific changes in the protein patterns of sodium hypochlorite-treated isolates, with major changes involving a subunit with

molecular weight of about 75,000.

12. Rhee, K.C., Cater, C.M. and Mattil, K.F. 1972. Simultaneous recovery of protein and oil from raw peanuts in an aqueous system. J. Food Sci. 37:1, 90-93.

Abstract: The feasibility of using an aqueous system for the simultaneous recovery of peanut oil and food grade protein concentrates and isolates directly from raw peanuts was investigated. The effects of such pertinent processing parameters as degree of grinding, solids-to-solvent ratio, extraction time and temperature, pH of extraction and protein precipitation and various salts at different concentrations on the recovery of oil and protein concentrates and isolates were determined. Under optimized conditions, approximately 96% of the oil and 94% of the proteins present in the peanuts were recovered when protein concentrates were prepared by employing an initial isoelectric centrifugation procedure whereas approximately 92% of the oil and proteins were recovered under the conditions of protein isolate preparation by an initial alkaline extraction method.

13. Rhee, K.C., Cater, C.M. and Mattil, K.F. 1973. Effect of processing pH on the properties of peanut protein isolates and oil. Cereal Chem. 50:3, 395-404.

Abstract: Peanut protein isolates and oil were prepared from raw peanuts using an aqueous system at several different pH values for protein extraction and precipitation. Some of their physical and chemical properties, as well as the extent of their recoveries, were determined in order to compare the effects of pH during preparation of isolates on the quality and yield of the products. The maximum recoveries of both protein and oil from raw peanuts were obtained at pH 8.0, and extraction pH values higher than 8.0 considerably reduced the protein solubility of the isolates with no significant increases in the recovery of the proteins. Higher pH values also increased the loss of oil through saponification. All four isolates remained stable when heated; no protein coagulation occurred even if isolates were heated at 95°C. for 30 minutes. Solution viscosities were quite low at all protein concentrations as compared to other vegetable proteins, and the pH of extraction and precipitation of the isolate significantly influenced viscosity characteristics.

14. Rhee, K.C., Mattil, K.F. and Cater, C.M. 1973. Recovers protein from peanuts. Food Engineering 45:5, 82-86.

Summary: Texas A&M has developed practical techniques for simultaneous recovery of protein and oil from peanuts. Refinements of the techniques are necessary before commercial production can be undertaken. There are two main ways of producing peanut concentrates and isolates. One is a solvent extraction, the other aqueous. Aqueous oil-milling makes it possible to inactivate aflatoxins with alkaline or oxidative agents which can be used at different stages of the

operation. Based on oilstock peanuts at 8.54 cents per pound shelled, manufacturing costs are about 17¢ per pound of concentrates, 28¢ per pound of isolates. Peanut concentrates are very soluble below pH 3.5 or above 6.5, heat stable, milky white in color, and bland in taste. The most limiting amino acids are lysine and methionine. It appears feasible to use them in a number of meat products as extenders.

15. Rhee, K.C., Cater, C.M., Mattil, K.F. 1973. Aqueous process for pilot plant-scale production of peanut protein concentrate. J. Food Sci. 38:1, 126-128.

Abstract: The feasibility of producing a peanut protein concentrate using an aqueous system has been evaluated on a pilot plant scale. The recovery of oil, which is economically important, was critically influenced by grinding methods and conditions and washing of the recovered solids, thus reducing the oil content of the concentrate and increasing the oil recovery. Under the present operating conditions approximately 92% of the protein in the raw material was recovered as a protein concentrate and 89% of the initial oil as free oil. The cost of production was estimated as 23¢/lb of protein.

16. Schmidt, R.H. and Mendelsohn, P.H. 1976. The effect of heat treatment on functionality of peanut/dairy protein blends. Presented at the 61st annual meeting of the American Association of Cereal Chemists, New Orleans, LA, October 5-8, 1976.

Abstract: The potential utilization of peanut protein as an extender for dairy protein depends upon compatibility to the dairy product ionic environment and upon interaction with dairy proteins as effected by heat processing. Research was undertaken to investigate the effect of heating on solubility and gelation properties of various peanut/dairy protein blends. Factors investigated were protein formulation, protein concentration, pH, sodium chloride and calcium chloride concentration. Protein formulations included peanut flour and peanut protein isolate blended at various levels with nonfat dry milk, sodium caseinate and calcium caseinate. Heat treatments varied from 60° to 90°C for 30 to 60 minutes. Solubility of peanut protein preparations at low $CaCl_2$ concentration was maximal with higher heat treatments. The addition of $CaCl_2$ to 0.03 M or the presence of milk protein altered the effect of heat treatment on apparent protein solubility. The gelation properties of gel strength and rate of gelling were directly related to temperature and heating time for the protein blends studied. Increased peanut protein concentration increased gelation at the higher heat treatments. Attempts were made to optimize formulation, ionic environment and heat treatment for maximal gelation properties.

17. Stoloff, L., Trucksess, M. and Martinez, W. 1976. The fate of aflatoxins in the preparation of protein concentrates and isolates from contaminated peanut and cottonseed flours. J. Food Sci. 41:5, 1251-1253.

Abstract: With the assistance of the laboratories of six major soybean protein producers, simulated commercial protein concentrate and isolate processes were applied to aflatoxin-contaminated peanut and cottonseed flours to determine the fate of the aflatoxins. Processes for producing concentrate by washing the flour at the protein isoelectric point (pH 4.5) were ineffective in separating the aflatoxin from the products, but a process using an aqueous alcohol wash accomplished a 90% reduction in the aflatoxin level of the concentrate compared to the flour. Processes for producing isolate by protein dissolution in alkali and its recovery by precipitation at the isoelectric point resulted in some aflatoxin loss but an increase in the aflatoxin concentration associated with the protein isolate compared to the original flour. However, a process applying carbon adsorbent to the alkaline solution accomplished a 90% reduction in the aflatoxin level of the isolate.

18. High protein peanut fiber, 1976. Food Processing 37:11, 71.

Summary: High protein food extender and replacement derived from peanuts is the result of new processing technology which eliminates tannin, requires no chemical additives and preserves the protein from denaturation. It can be blended up to 60% without altering the original flavor. Protein flour is recommended as an extender in the dairy, bakery, meat, and other food fields.

19. Peanut flakes duplicate texture/taste of egg, meat, and dairy products, 1976. Food Processing 37:1, 42-43.

Summary: A unique, patented peanut flake process developed at Clemson University has been licensed to CVI Development Corporation. Operations are now on a pilot plant basis. The flakes produced are white, bland, and instantly rehydratable. The PER value is around 2.0. Full-fatted peanut flakes have 29.4% protein, partially defatted 41% and the defatted 58.7%. Basic research at Clemson University showed that the flakes were highly acceptable when used as an extender in chicken and turkey rolls, sandwich spreads and dips, candy and other foods.

20. Peanut flakes extend, fortify entrees, 1976. Food Product Development 10:6, 39.

Summary: Peanut flakes provide a protein food extender with many advantages. It hydrates instantly, is bland, and takes on structural characteristics of other foods. It can replace 50% of the ground beef in stuffed peppers, 66% of the chicken in chicken loaf.

21. Peanuts -- inexpensive protein isolate, concentrate. 1973. Food Processing 34:4, F28.

Summary: A method of processing and, when necessary, detoxifying peanuts has been developed at Texas A&M and results in a peanut protein isolate and concentrate at a price similar to soy. Peanut protein is bland, can be texturized, is almost white and virtually odorless.

E. Rapeseed proteins

Although most of the literature cited previously is found in United States technical literature, the references for rapeseed are largely Canadian. This is because rapeseed is being investigated by technologists in Canada and other countries as an alternative to soy. Although the United States may never produce significant amounts of rapeseed protein itself, the development of rapeseed technology in other countries could have a major impact on soy exports from this country. The removal of glucosinolates has been the main processing problem in producing rapeseed proteins.

1. El Nakrasky , A.S. et al. 1975. Nutritive values of rapeseed meals and rapeseed protein. Nutr. and Metab. 19:3-4, 145-152.

<u>Abstract</u>: Defatted meals of two new varieties of rapeseed (Brassica napus), Erglu and Lesira, and protein isolates prepared therefrom, were fed to chicks that had been depleted of their embryonic protein reserve. First, the animals were fed at a 12% protein level, half of it from rapeseed meal, or a rapeseed protein isolate and, subsequently, at a 20% level, all of it from rapeseed products. Feed consumption, weight gain and protein efficiency ratio revealed better performance of the protein isolates as compared to the corresponding meals. This is attributed to the favorable amino acid patterns of these isolates and the absence of glucosinolates. Erglu meal, too, is eminently suitable as a supplement to chicken feed, whereas Lesira meal, although its amino acid pattern is adequate and similar to that of Erglu meal, showed detrimental effects, probably due to its high glucosinolate content.

2. Gill, Z.A. and Tung, M.A. Rheological, chemical and microstructural studies of rapeseed protein dispersions. 1976 Can Inst. of Food Sci and Tech J. 9:2, 75-83.

<u>Abstract</u>: Purified isolates of an alkali-soluble protein were prepared from commercially defatted rapeseed (Brassica campestris) meal. Aqueous dispersions of the protein were studied by chemical, physical, and microscopical methods. The protein was found to be chromatographically and electrophoretically pure and had a molecular weight of 129,200 daltons (12 S) when measured by conventional sedimentation equilibrium ultracentrifugation. At pH 9.5 this globulin (water insoluble) behaved as an acidic protein, migrating toward the anode in disc gel electrophoresis. When treated with 5 M urea, the molecule or aggregate of molecules fragmented into subunits. When hydrated, fixed and prepared for histochemical tests, the isolate stained with Schiff's reagent, thereby indicating the presence of a considerable amount of carbohydrate. Electron microscopy of the protein fixed at pH 7.0 revealed that it was highly agglomerated, probably due to a charge effect. Heating resulted in gelation of aqueous dispersions containing 5.4% of the protein and considerable thickening was observed on heating dispersions of 1% protein. Blocking the free-SH groups with p-mercuribenzoate did not prevent gelation.

3. Gillberg, L. and Tornell, B. 1976. Preparation of rapeseed protein isolates. Precipitation of rapeseed proteins in the presence of polyacids. J. Food Sci. 41:5, 1070-1075.

Abstract: The precipitation of alkaline extracted rapeseed proteins by addition of acid in the presence of different acidic polymers has been studied. The yield and the nitrogen and dry matter contents of the isolates were found to depend on the ionic composition of the extract, the nature and amount of added polymer and the pH of precipitation. The acidic polymers studied were hexametaphosphate, CMC or different DP and DS, polygalatouronic acid, alginate and kappa-, iota- and lambda-carrageenans. With all of these polymers, it was possible to obtain a quantitative or almost quantitative recovery of the dissolved proteins. Except for the carrageenans, all of the polymers produced a high increase in the dry matter content of the precipitates.

4. Gillberg, L. and Tornell, B. 1976. Preparation of rapeseed protein isolates. Dissolution and Precipitation Behavior of Rapeseed Proteins. J. Food Sci. 41:5, 1063-1069.

Abstract: The dissolution of nitrogen and phosphorus containing substances from defatted rapeseed, and the subsequent precipitation of these substances by acid was studied. The dissolution of the substances of interest was found to vary in a complicated manner with the pH of extraction. This was especially true for the dissolution of inositol hexaphosphoric acid (phytic acid) and the other phosphorus containing substances. The presence of phytic acid in the protein extracts strongly affected the nitrogen recovery, the useful pH range for precipitation and the dry matter content of the precipitates. These effects were different with extracts prepared at different pH values. With an extract prepared at pH 11.1, addition of sodium phytate increased the yield from about 35% to 75% of the extracted nitrogen and the dry substance content of the precipitate from 16% to 33%.

5. Josefsson, E. and Uppstrom, B. 1976. Influence of glucosinolate and native enzymes on the nutritional value of low-glucosinolate rapeseed meal J. Sci. Food Agric. 27:5, 433-437.

Abstract. This study attempted to find out whether the low content of glucosinolates in the seed of the rapeseed cultivar Bronowski significantly affects the nutritional value of the seed meal. Glucosinolates were extracted from unheated meal with cold acetone, a process giving rise to only a slight inactivation of enzymes. Mice fed with a diet containing this meal as the protein source showed similar growth, feed intake, and protein efficiency ratio to mice fed with heat-treated meal. When glucosinolates were added to the acetone-extracted meal, bringing them to about the same amount as before the acetone extraction, the growth response of the mice was as poor as that of mice fed with unheated, unextracted meal. Thus, even such low amounts of glucosinolates as found in Bronowski seed meal significantly affect the nutritional value of the diet as long as the appropriate enzymes are present. Besides myrosinase, other enzymes influencing the hydrolysis of glucosinolates appear to exist in the meal.

6. Kodagoda, L.P., Nakar, S. and Powrie, W.D. 1973. Some functional properties of rapeseed protein isolates and concentrates. Can. Inst. Food Sci Technol. 6:4, 266-269.

Abstract: Protein isolates and concentrates obtained from rapeseed flour by a successive water, HCl, and NaOH extraction process were subjected to baking, emulsification, and whipping tests. In baking, a 5% replacement of wheat flour with rapeseed protein isolates and concentrates decreased loaf volume by 10 to 15% and 20% respectively. Addition of 0.5% emulsifier (Atmul 124) restored loaf volume to most breads; 10 tc 15% larger loaf volume for the water and HCl extracted isolate breads than the all-wheat control; 8% inferior loaf volume for the protein concentrate breads except for the NaOH extracted concentrate (12% larger loaf volume). Whipping tests with 3% replacement of egg white protein by isolates or concentrates generally resulted in a decreased, specific volume compared to the all-egg control. An exception was the HCl extracted isolate with a 10% larger specific volume than the control. All fractions improved foam stability; particularly, meringues containing the water extracted isolate showed no sign of drip for 1.5 h. The water extracts displayed highest emulsification capacity; 45 ml of corn oil per 100 mg of protein in the isolate compared to approximately 35 ml for other fractions. Emulsions containing the HCl extract showed remarkable stability; 200 minutes compared to 3 minutes for the control. No significant correlation was observed between the solubility of rapeseed protein products and their functional properties.

7. Kozlowska, H., Saber, M.A. and Sosulski, F.W. 1975. Phenolic constituents in rapeseed flour. Can. Inst. of Food Sci. and Tech. 8:3, 160-163.

Abstract: Total ether-extractable phenolic compounds in Span rapeseed constituted 1.5 and 0.2% of dehulled and diffusion-extracted flours, respectively. The principal phenolic constituents tentatively identified in dehulled flour were p-hydroxybenzoic, trans-cinnamic and sinapic acids while small quantities of p-coumaric, ferulic, caffeic, chlorogenic and two unknown acids were also detected by gas-liquid chromatography. Five phenolic acids which occurred in the ester form in the dehulled flour also occurred in the diffusion extracted extracted flour. The sinapic acid ester constituted 85% of the phenolic compounds in the diffusion extracted flour and because of its low taste threshold, may contribute adverse flavors to rapeseed food products.

8. Quinn, J.R. and Jones, J.D., 1976. Rapeseed protein. pH solubility and electrophoretic characteristics. Can. Inst. of Food Sci. and Tech J. 39:1, 47-50.

Abstract: Rapeseed meal was extracted in water, in 5% NaCl, or in 5% CaCl at pH values ranging from 2.5 to 11.0. The extracted proteins were subjected to dissociating conditions and examined for molecular weight distribution by SDS gel electrophoresis and for isoelectric point patterns by gel electrofocusing. The pH solubility profiles demonstrated the relatively high solubility of rapeseed protein over the acidic pH range and consequently, the difficulty of protein isolate production by traditional oilseed technology. Electrofocusing resolved over 30 protein species which SDS electrophoresis showed to be mainly distributed among only 3 molecular weight groupings.

9. Radwan, M.N. 1976. Solubility of rapeseed proteins in aqueous solutions. J. Am. Oil Chem. Soc. 53:1, 142-144.

Abstract: The solubility of the protein of the dehulled and defatted 'Tower' variety of rapeseed in aqueous solutions was determined at temperatures of 25, 35, 45, and 55 C in the pH range of 1-13. It was found that the points of minimum solubility occur at pH values of 4.5, 4.8, 7.0, and 7.2, respectively, for the above four temperatures. No color change of the meal was observed at or near the minimum solubility point. The aqueous solutions were prepared at the selected pH values by using either NaOH or H_2SO_4. The purpose of this work was to determine the conditions of minimum solubility of the rapeseed protein to remove the toxic compounds and to minimize protein loss. The presence of the indigestible fibrous materials and the thioglucosides is the main impediment to use of rapeseed.

10. Sosulski, F., Humbert, E,S., Bui, K. and Jones, J.D. 1976. Functional properties of rapeseed flours, concentrates and isolate. J. Food Sci. 41:6.

Abstract: The functional properties of rapeseed meal, flours, protein concentrates and isolate were evaluated in comparison with those of soybean. Generally, rapeseed products were lower in protein but higher in crude fiber and ash contents than the corresponding soybean flour, concentrate or isolate. Rapeseed flours were comparable to soybean flour in water absorption but showed much higher nitrogen solubility, fat absorption, oil emulsification, whippability and foam stability. The viscoamylograph curves for rapeseed flours were characterized by intermediate peak and high cold viscosities, but their gelation properties were poor. Unfortunately, flour from the low glucosinolate cultivar, Tower, contained 1.2 mg/g of glucosinolates, primarily oxazolidinethione, and only the detoxified concentrates and isolate would be safe for human consumption. Rapeseed concentrates and isolate showed excellent water and fat-holding capacity and the isolate was high in oil emulsification and whipping characteristics. While superior to soybean products in most functional tests, the utilization of rapeseed products may be limited by green or brown colors in the aqueous slurries.

11. Stanley, D.W., Gill, T.A., deMan, J.M. and Tung, M.A. 1976. Microstructure of rapeseed. Can. Inst. of Food Sci. and Tech. 9:2, 54-60.

Abstract: The microstructure of the rapeseed kernel was studied by light microscopy, scanning electron microscopy and transmission electron microscopy. The structural effect of mechanical dehulling was investigated and attempts were made to localize a major alkali-soluble 12 S glycoprotein. Rapeseed is a small, spherical kernel characterized by the major cell inclusions common to most oilseeds, i.e. nuclei, oil droplets and protein bodies or aleurone grains. Dehulling by pneumatic attrition produced changes in microstructure that may reflect a loss of cellular material, 12 S glycoprotein does not appear to be localized in any specific part of the seed.

12. Thompson, L.U., Allum-Poon, P. and Procope, C. 1976. Isolation of rapeseed protein using sodium hexametaphosphate. Can. Inst. of Food Sci and Tech. J. 39:1, 15-19.

Abstract: The suitable conditions for the extraction and precipitation of proteins from rapeseed flour (RF) using sodium hexametaphosphate (SHMP) were determined. Rapeseed protein isolate (RI) was then prepared and analyzed for chemical composition, biological value, color and yield. The highest nitrogen yield was obtained when RF was double extracted with 2% SHMP at pH 7.0, first with a RF to solvent ratio of 1:10 and second with a ratio of 1:6 at 25°C for 30 minutes. The maximum precipitation of the extracted nitrogen was observed in the extract diluted with an equal volume of distilled water and adjusted to pH 2.5. The RI contained on dry basis 72.6% protein (N x 6.25), 12.2% ash, 0.7% crude fiber, 7.6% nitrogen free extract, 3.21% phosphorus, trace amounts of glucosinolate and no myrosinase activity. Its PER was equal to that of cheese whey protein concentrate and greater than that of casein. RI was yellow at pH 2.5 and tan at pH 7.0. Ether extraction lightened the color of the neutralized RI. Thirty-four percent total solids yield and 53% protein yield were observed in the preparation of RI.

13. Wetter, L.C. and Youngs, C.G. 1976. A thiourea-UV Assay for total glucosinolate content in rapeseed meals. J. Am. Oil Chem. Assoc. 53:4, 162-164.

Abstract: A rapid and sensitive method for the determination of the total glucosinolate content in rapeseed is described. The method is based on the specific UV absorbance of the thioureas and oxazolidine-2-thiones. Results obtained were confirmed by gas-liquid chromatography. Recoveries varying from 94 to 103% were obtained for samples containing mixtures of isothiocyanate and oxazolidine-2-thione (a total of 0.25 to 0.78 mg per assay). The relative standard deviation for rapeseed meals varied from 4 to 10% for the total glucosinolate content (expressed as 3-butenylisothiocyanate) and depended on the size of sample taken. The relative standard deviation for oxazolidine-2-thione varied from 5 to 35% for the same meal. The lower limit of detection for rapeseed meal is of the order of 0.25 mg of 3-butenylisothiocyanate per g.

14. Rapeseed-versatile oil enters market, is possible protein source. 1973. Food Processing 34:4, F 24-25.

Summary: Because of tariff regulations, rapeseed is not currently imported into the U.S. However, large production of the plant could affect export of US domestic oils to foreign markets. Research in Canada has developed methods of removing thioglucoside from the proteinaceous meal. Thioglucoside binds iodine and has been implicated in thyroid disorders when consumed in large quantities. The meal contains amino acid ratios similar to soy. It may become possible for Canada to produce its own vegetable protein isolates from a domestic crop.

F. Sunflower protein

Research on sunflower seed protein has centered largely around the identification and removal of phenolic compounds. Chlorogenic acid, the principal phenol present in sunflower seeds, gives a green color to sunflower protein products. Thus although sunflower may have certain desirable functional properties, the presence of phenols creates an additional processing problem.

1. Fan, T.Y. and Sosulski, F.W. 1976. New techniques for preparation of improved sunflower protein concentrates. Cereal Chem. 53:1, 118-125.

Abstract: Countercurrent extractions of sunflower flour with water, acid, or alcohol, and countercurrent diffusion of sunflower seed with acid, were more efficient in solvent use and chlorogenic acid removal than batch extractions with fresh solvents. With five- to six-stage countercurrent procedures, about 90% of the chlorogenic acid was extracted from sunflower flour at a solvent-to-flour ratio of 6:1 (v/w) or from seed at a solvent-to-seed ratio of 3:1 (v/w). The resulting protein concentrates contained over 70% protein and were light in color under alkaline pH conditions. Acid extraction of the flour produced the most soluble protein concentrate, but 40% of the flour solids and 25% of the flour proteins were lost in the liquor or extract. Acid extraction at 80°C or water extraction of protein-denatured flour improved the rate of chlorogenic acid extraction, but protein losses in the extract remained high. Aqueous ethanol was an efficient solvent for the removal of chlorogenic acid from the flour, and the protein concentrate yield of 77-78% accounted for 95-97% of the flour proteins. Acid diffusion of the seed gave intermediate-to-high yeilds of protein concentrate with low chlorogenic acid levels. Acid diffusion rates were temperature-dependent and 80°C was required to remove 90% of the chlorogenic acid from sunflower seeds. Important factors in assessing the relative merits of the various processes are the need for recovery of the solvent in the alcohol process, the relative ease in handling of products during acid diffusion of the seed, and the nitrogen solubility of the protein concentrates.

2. Huffman, V.L., Lee, C.K. and Burns, E.E. 1975. Selected functional properties of sunflower meal. J. Food Sci. 40:1, 70-74.

Abstract: Sunflower meal exhibits excellent functionality for possible use in specialized food. The most promising properties are emulsion capacity, water adsorption, water retention and aeration properties. With low mixing speeds and rapid rates of oil addition, optimum emulsion capacity occurs at pH 7. Water adsorption capacity increases as the native protein concentration increases among varieties. Optimum foam volume and stability are produced at pH 9 with a meal concentration of 8%, and a whipping time of 12 min at 15°C. At this pH, foams are a definite green color due to the oxidation of chlorogenic acid. However, the combination of sucrose and potassium bitartrate added to the foam produces a bright white foam with excellent volume and stability.

3. Kelara, A., Humbert, E.S. and Sosulski, F.W. 1972. Nitrogen extractability and moisture adsorption characteristics of sunflower seed products. J. Food Sci. 37:5, 771-773.

Abstract: Diffusion-extracted (DE) sunflower meal and protein isolate were compared with untreated samples for their nitrogen extractability and moisture adsorption. Nitrogen extractability values of 90% were found at pH 7 or above in the untreated meal, whereas a maximum solubility of only 70% was achieved at pH 9.0 in the DE meal prepared at 60°C. DE meal prepared at 80°C had low solubility over a pH range of 1-11 which indicated substantial denaturation of the sunflower proteins. The untreated isolate showed a sharp minimum solubility point in contrast to the low solubility of the DE isolate over a pH range of 3-7. Moisture adsorption values for the samples held at 5, 20, and 30°C indicated little difference in moisture contents at relative humidities of 11-55%. At higher levels, however, the untreated meal adsorbed more moisture than the DE meal. A reverse trend was noticed for the isolates as the moisture content of the DE isolate was higher than the untreated sample. The rate of moisture uptake by sunflower kernels was slower than that observed with rapeseed or soybean meats and lower total moisture contents were observed after a 4-hr soaking period.

4. Lin, M.J.Y., Humbert, E.S. and Sosulski, F.W. 1974. Certain functional properties of sunflower meal products. J. Food Sci. 39:2, 368-370.

Abstract: Certain functional properties including water absorption, fat absorption, emulsification, whippability and foam stability were determined on the sunflower flour, protein concentrates and isolate. The results were also compared to those obtained on soy products. Data on water and fat absorption studies suggest that soy products are more hydrophilic in nature while sunflower material exhibited greater lipophilic properties than the soy products. Emulsification tests showed that sunflower flour was superior to all other soy and sunflower products. In general, whipping properties of soy and sunflower isolates were similar, while less whippability was observed for the soy flour and protein concentrates. Whipped foams produced by soy and sunflower protein isolates and sunflower flour were more stable than soy flour, soy, and sunflower protein concentrates.

5. Provansal, M.M.P., Cuq, J.A. and Cheftel, J. 1975. Chemical and nutritional modifications of sunflower proteins due to alkaline processing. Formation of amino acid cross-links and isomerization of lysine residues. J. Agric. Food Chem. 23:5, 938-943.

Abstract: Treatment of sunflower protein isolates with sodium hydroxide reduces their content of cystine, arginine, threonine, serine, isoleucine, and lysine, in agreement with known data from alkaline hydrolysis of proteins. Unusual amino acid residues are formed during these treatments; using ion-exchange chromatography and high-voltage paper electrophoresis, alloisoleucine, ornithine, lysinoalanine, and lanthionine were identified. The presence of the latter two compounds indicates the formation of cross-links in the protein and may explain observed changes in the in vitro proteolytic digestibility. The formation of

ornighine and the decrease in arginine content appear to be the best indicators of the severity of the alkaline processing. Severe treatments with sodium hydroxide ($>$ 0.2 M, 80^{o}, 1 hr) also provoke a marked degree of isomerization of the L-lysine, residues into D-lysine, as demonstrated by both enzymatic and microbiological methods of analysis.

6. Sabir, M.A., Sosulski, F.W. and MacKenzie, S.L. 1973. Gel chromatography of sunflower proteins. J. Agric. Food Chem. 21:6, 988-993.

Abstract: The salt-extractable proteins in sunflower flour were characterized by gel chromatography, disk electrophoresis, and amino acid composition. The proteins from Commander, Majak, and Valley sunflower and a soybean control were 69-70% dispersible in 2.5% neutral salt solution. These proteins were separated into five fractions by gel chromatography on a standardized Sephadex G-200 column. The fractions I-V contained about 5, 49, 9, 24, and 12% of the extracted meal proteins, respectively, in the three sunflower varieties. After dialysis, fraction I contained a large proportion of nucleic acids, while chlorogenic acid appeared to be bound to only fraction V proteins. Molecular weight estimations indicated that, on the average, the five sunflower protein fractions were similar in molecular weight to the five soybean protein fractions. Sedimentation analyses of Valley fraction II showed that the major protein component in this fraction had a sedimentation coefficient of 12.R.S. The Valley proteins demonstrated fewer bands on disk electrophoresis at pH 8.9 than the soybean proteins. Amino acid analysis indicated that soybean was higher in lysine but lower in methionine than sunflower. Majak proteins were higher in lysine and methionine than Commander and Valley proteins. The major protein fraction II contained high proportions of isoleucine, phenylalanine, threonine, and nonessential amino acids. The fraction IV proteins were very rich in lysine and methionine, while the fraction V in each sunflower variety was very deficient in these essential amino acids.

7. Sabir, M.A., Sosulski, F.W. and Kernan, J.A. 1974. Phenolic constitutents in sunflower flour. J. Agric. Food Chem 22:4, 572-574.

Abstract: Phenolic compounds in Commander, Majak, and Valley sunflowers varied between 3.0 and 3.5 g of chlorogenic acid per 100 g of flour. Under neutral and alkaline conditions, sunflower protein solutions develop dark green and brown colors because of bonding with oxidation products of poly-phenolic compounds, especially chlorogenic acid. Therefore, a reducing agent was utilized in the present study to inhibit the formation of covalent bonds but 30% of the chlorogenic acid was nondialyzable and remained bound to the flour constituents. About one-half of the phenolic constituents were extracted with the soluble sunflower proteins by neutral salt solutions and about one-third of this fraction was also nondialyzable. Fractionation of the neutral salt extracts revealed that all of the soluble chlorogenic acid was associated with the low molecular weight components (mol wt $\leq$ 5000) in the third fraction on Sephadex G-25 and fraction V in Sephadex G-200 chromatography. The elution behavior on Sephadex gels, the low nitrogen contents, and the low amino acid recoveries demonstrated that these fractions were polypeptides and oligonucleotides. Rechromatography of fraction V on Sephadex G-200 in the presence of a strong hydrogen bonding agent, 7 M urea,

revealed that 68% of the salt-soluble polypeptides were hydrogen bonded and about 32% were apparently covalent bonded to chlorogenic acid in Commander sunflower.

8. Sabir, M.A., Sosulski, F.W. and Finlayson, A.J. 1974. Chlorogenic acid protein interactions in sunflower. J. Agric. Food Chem 22:4, 575-578.

Abstract: Eight of the ten phenolic compounds in the aqueous methanolic extracts from three varieties of sunflower were tentatively identified and quantitated by their spectrophotometric and chromatographic characteristics. Chlorogenic acid, one of its isomers, and caffeic acid constituted 70% of the total phenolic compounds in the flour of each variety. Compounds related to p-coumaric, isoferulic, and sinapic acids and a hydroxycinnamic acid-sugar ester were also detected by tlc and glc analyses. The sinapic acid like compound represented 15% of the total phenolic compounds in the three flours. Two minor components with long retention times were also present in the neutral fraction.

9. Sunflower seeds offer polyunsaturated oil, protein digestibility 1973. Food Processing 34:4, F21.

Summary: Sunflower meal, produced by hexane extraction of oil from the hulled seeds, drying and grinding, results in a highly digestible product containing 46% protein. Sunflower is approximately equivalent to soy or cotton seed in nutritive value. Food uses are currently limited to foods having a relatively high pH.

G. Miscellaneous oilseed proteins: safflower and sesame

Safflower and sesame seeds are two other oilseeds that could be used as protein extenders. However, the work on these products is still in the experimental stage.

1. Betschart, A.A. 1975. Factors influencing the extractability of safflower protein. J. Food Sci. 40:5, 1010-1013.

Abstract: Classical fractionation of safflower meal protein yielded 8, 31, and 28% of the meal nitrogen as water, salt, and alkali soluble, respectively. The water soluble fraction contained equivalent or larger quantities of the essential amino acids than did the meal. Conditions for extraction of total safflower meal protein included extracting a 5% (w/v) aqueous solution for 60 minutes at pH 9 and 25°C. Protein extraction was impaired when the meal was heated to temperature of 107°C or higher. At pH some 68, 80 and 83% of the meal nitrogen was extracted from a commercially desolventized meal, an expeller press cake meal and an unheated control meal, respectively.

2. Guerra, M.J. and Park, Y.K. 1975. Extraction of sesame seed protein and determination of its molecular weight by sodium dodecyl sulfate polyacrylamide gel electrophoresis. J. Am. Oil Chem. Soc. 52:3, 73-75.

Abstract: Sesame seeds are an important source of edible oil and protein. Studies were made on protein solubility of defatted sesame seed meal in aqueous solution over various pHs or in various salt solutions. Maximum solubility was found in alkaline solution, and the proteins were almost insoluble at acid solution. The solubility of protein in NaCl or $CaCl_2$ solution was increased upon increasing the salt concentrations up to 1 M. In Na_2SO_3 or Na_2HPO_4 solution, the solubility of protein was higher at lower salt concentrations but decreased at higher salt concentrations at pH 8. Extractable sesame seed proteins in salt solution separated into seven fractions electrophoretically (sodium dodecyl sulfate-polyacrylamide gel electrophoresis. The molecular weight of the seven fractions were 51,000, 31,000, 28,500, 25,500, 21,800, 20,500, and 17,900.

V. Grain Proteins

Although the search for inexpensive sources of protein extenders has focused on many obvious as well as unusual sources, relatively little research has been undertaken on cereal grains which are among the most available protein sources. The grains with the most promise include oats, corn and wheat. Oat proteins have the best amino acid balance. Corn has good nutritional and functional properties but the literature indicates that flavor improvement is necessary. Because of the incompleteness of its protein, wheat is usually considered as a supplement to other proteins. The usual limiting amino acid in cereal grains is lysine, thereby making soy/grain blends attractive. Research is being undertaken to genetically improve grains for both functional and nutritional qualities. One of the most interesting genetic blends is triticale, a blend of wheat and rye, in which the rye supplies additional lysine.

While at the present time cereal grains are not used as extenders by themselves, there is much potential. A growing interest in a combination of grains with other protein sources is described in Section VII.

A. Corn Proteins

1. Nielsen, H.C., Inglett, G.E., Wall, J.S. and Donaldson, G.L. 1973. Corn germ protein isolates - preliminary studies on corn preparation and properties. Cereal Chem. 50:3, 435-443.

Abstract: Commercial corn germ was extracted with hexane and ground to a meal. Protein was solubilized by two extractions in a high-speed blender at either a 10:1 or a 5:1 solvent:meal ratio. The first solvent was water containing 10 mg sodium hydroxide per g germ meal (pH 8.7); the second was water only. Protein in the extract was precipitated by adjusting to isoelectric pH (4.7). The protein precipitate, after being washed with water, was adjusted to pH 7.0 and freeze-dried. The neutralized isolate extracted at a 5:1 solvent:meal ratio was dialyzed against distilled water for 48 hr to reduce ash content before freeze-drying. Proximate analysis of the dialyzed isolate was 74% protein (N x 5.4); 4.3% ash, most of which was phosphate; and 0.08% fiber. The protein in the isolate contains 6% lysine with a good balance of other essential amino acids. Mild flavor, light tan color, solubility at neutral and low pH, and ability to stabilize an oil-in-water emulsion are some properties of this corn germ protein isolate that indicate its potential for many food uses. Corn germ isolate in its present state of development seems to have good nutritional and functional properties. However, it is not as pure nor as light-colored as sodium caseinate or soy isolate, and its flavor is not as bland as that of sodium caseinate. Work is currently under way to improve the purity, flavor, and color of corn germ isolate.

2. Nielsen, H.C., Inglett, G.E., Wall, J.S. and Donaldson, G.L. 1973. New corn protein isolate — nutritional, functional. Food Engineering 45:4, 4, 76-77.

Abstract: A corn protein isolate with a good balance of essential amino acids has been extracted from oil-free germ meal. Its mild flavor, light tan color, solubility at neutral and low pH, and ability to stabilize oil-in- water emulsions show potential for protein supplementation and other food uses. Estimated production cost is about 8 cents per pound more than that of soy isolate. Work is in progress to improve the purity, flavor, and color of the corn isolate. Details of the isolation procedure and isolate properties are described.

3. Wu, Y.V. and Sexson, K.R. 1976. Protein concentration from normal and high-lysine corns by alkaline extraction: Preparation, J. Food Sci. 41:3 pp. 509-511.

Abstract: Protein concentrates and by-products produced by alkaline extraction from ground corn having normal and high contents of lysine were analyzed for amino acid composition, protein, starch, fat, ash, fiber, and various neutral carbohydrates. A high-lysine concentrate contained 65% protein (nitrogen x 6.25) with 4.7 g lysine and 4.0 g total sulfur amino acids per 16 g nitrogen recovered. The minimum nitrogen solubility of the concentrates was 3%-5% near pH 5.5. The protein concentrates have good functionality relative to their emulsifying activity, emulsion stability and hydration capacity.

4. Textured protein product in-plant. 1972. Food Processing 33:6, F-5.

Summary: A textured protein product is produced by using a starch (corn) - protein blend in the ratio of one part starch to three parts protein. The resultant product is unusually resistant to textural degradation. Starch used is a "genetically modified common corn," and protein can be soy isolate or other vegetable protein.

5. Update application of corn germ flour. 1973. Food Eng. 45:4, 78.

Summary: Data has been collected at the USDA's Western Regional Labs on cooking, baking, characteristics and taste evaluations of corn germ flour containing about 25% protein. Yield increase in beef patties increased from 70% in the control patty to 77% at the 10% germ-flour level. Protein and fat decreased, while ash and fiber increased.

B. Oat Proteins

1. Cluskey, J.E. et al. 1973. New proteins from oats. Food Engineering 45:8, 99.

Abstract: USDA researchers have developed two groups of protein concentrates—one from wet-milled ground oat groats and the other from air-classified, finely ground oat groats and flours. The oat proteins have solubility, hydration capacity, and emulsion stability necessary for use in foods and beverages. Details of processing are given.

2. Cluskey, J.E., Wu, Y.V., Wall, J.S., and Inglett, G.E. 1973. Oat protein concentrate from a wet-milling process: Preparation, Cereal Chem. 50:3, 475-481.

Abstract: A wet-milling process was developed to produce protein concentrates, starch, and residue fractions from dry-milled oat varieties having moderate- (Wyndmere) and high-protein contents (Garland). Different solvents and pH values were evaluated for their effectiveness in extracting an oat protein concentrate in good yield. The optimum yield of protein was obtained in dilute alkali solution (pH 9). Starch and protein were separated from bran by sieving the alkaline dispersion. After the fine suspension was centrifuged to separate pure starch (0.05% nitrogen), the protein solution was adjusted to pH 6 and freeze-dried. The protein content (nitrogen x 6.25) of the concentrate varied between 59% and 89%, depending on the dry-milled fraction and process used, and accounted for up to 88% of total protein in the starting material. This simple process for producing an oat protein concentrate may have commercial potential. Oats have good quality protein and a high-protein content. The increasing availability of high-protein oats and the favorable solubility characteristics of oat proteins suggest that it may be feasible to make an oat protein concentrate having good nutritive value.

3. Pomeranz, Y., Shands, H.L., Robbins, G.S. and Gilbertson, J.T. 1976. Protein content and amino acid composition in groats and hulls of developing oats. J. Food Sci. 41:1, pp. 54-61.

Abstract: Protein content and amino acid composition were determined in groats and hulls of three oat cultivars harvested at four stages of development. Protein content was slightly higher in mature than in immature groats. In the hulls, protein content decreased during development to about one-third the content of immature hulls. The large decrease in protein content of the hulls was accompanied by little change in amino acid composition. In the groats, however, there were consistent and large decreases in concentrations of lysine, threonine and aspartic acid and an increase in glutamic acid. The results suggest that in addition to deposition of storage protein in groats, amino acids are translocated from the hulls to the groats.

4. Wu, Y.V. and Strongfellow, A.C. 1973. Protein concentrates from oat flours by air classification of normal and high protein varieties. Cereal Chem. 50:3, 489-496.

Abstract: Oat groats as well as first and second flours, from a high-protein variety (Garland) and from a normal-protein variety (Sioux) were finely ground and air-classified to yield fractions with protein contents (nitrogen x 6.25) ranging from 4% to 88%. Air classification of the oat flours produced a unique fraction (83% to 88% protein) not previously observed for wheat, rye, corn, sorghum, or triticale flours. This fraction (2 to 5% by weight) accounted for 14, 16, and 7%, respectively, of the total protein in first and second flours and groats. The next fraction (25 to 29% by weight) with 15 to 39% protein accounted for total protein from flours of 38 to 48%, and with 21 to 29% protein from groats, 31 to 33%. The first and second flours gave a better air-classification response than ground groats, and the high-protein variety gave better results than normal-protein oats. Amino acid analysis of all fractions indicated high-lysine levels from 3.9 to 5.0 g per 16 g nitrogen and adequate total sulfur amino acids. Data showed that air classification of oat flours and ground groats produced protein concentrates of good amino acid composition and could provide a new food ingredient suitable for a variety of uses.

5. Wu, Y.V., Cluskey, J.E., Wall, J.S. and Inglett, G.E. 1973. Oat protein concentrates from a wet-milling process: composition and properties. Cereal Chem. 50:3, 481-488.

Abstract: Protein concentrates, starch, and residue fractions produced by a wet-milling process from ground oat groats with moderate- and high-protein contents were analyzed for amino acid composition, protein, starch, fat, fiber, ash, and various neutral carbohydrates. The concentrates, which have a bland taste, contain from 59 to 75% protein (nitrogen x 6.25) with 3.9 to 4.1 g lysine and 3.3 to 4.3 g total sulfur amino acids per 16 g nitrogen. The concentrates are low in fiber (0.1% to 0.2%), have 3.5% to 4.5% ash, no starch, and from 2.2% to 23.3% total carbohydrate. Protein concentrate from Garland groats has 10.1% fat, whereas defatted Wyndmere groats give a protein concentrate with 0.3% fat. The starch fraction is essentially composed of pure starch without any other carbohydrate. Protein concentrate from defatted Garland groats has a nitrogen solubility of 83% at pH 2.1, a minimum solubility (15%) around pH5, and 95% solubility at pH 11.4.

C. Wheat Proteins

1. Grant, D.R. 1973. The modification of wheat flour proteins with succinic anhydride. Cereal Chem. 50:3, 417-428.

Abstract: Treatment of wheat flour with succinic anhydride in aqueous dioxane suspension results in the conversion of 95% of the protein to derivatives soluble in water. Decreasing the pH below 5.0 results in precipitation of most of these derivatives. A substantial fraction was precipitated at 1% Na_2SO_4 concentration, but another fraction was insensitive to high salt concentrations. Sensitivity to low pH and salt concentration diminished as the dioxane content of the system increased. G-100 Sephadex chromatography and viscosity studies indicated that the succinylated derivatives are more extensively dissociated in solution than untreated flour proteins in a dilute acetic acid extract. Polyacrylamide gel electrophoresis and ultracentrifugal analysis indicated that some association phenomena still occur unless the derivatives are dissolved in concentrated urea solutions. Gel electrophoresis of native and succinylated solutions of serum albumin, pepsin, and lysozyme indicated that the succinylation of a single protein species is likely to produce a heterogeneous product.

2. Saunders, R.M., Connor, M.A., Edwards, R.H., Kohler, G.O. 1975. Preparation of protein concentrates from wheat shorts and mill-run by an alkaline process. Cereal Chem. 52:1, 93-101.

Abstract: Protein concentrates were prepared from wheat shorts and mill-run by a wet process. The millfeed was suspended in water, adjusted to a specific alkaline pH, and extracted for a specified time interval. The mixture was squeezed to separate the liquid phase, which also contained starch granules, from fibrous material. Fractions rich in protein, starch, and fat and low in fiber were prepared from the squeezed juice by heat coagulation or acid precipitation. The yield and composition of concentrates as a function of extraction pH are described. The concentrates generally contained about 30% to 40% protein; 36% to 60% starch, and 7% to 11% fat, and were obtained in yields of 15% to 25%. Removal of starch from the squeezed juice before precipitation of the protein yielded products containing approximately 64% protein and 19% fat. After removal of the precipitated concentrates the residual juice was recycled to be used as the extracting medium for another batch of millfeed; an eight-time recycling experiment is described. Addition of bisulfite during processing resulted in lighter-colored products.

3. Woerman, J.H. and Statterlee, L.D. 1974. Extraction and nutritive qualities of wheat protein concentrate. Food Technol. 28:7, 50-52.

Summary: The extraction of wheat bran and shorts at alkaline pH yielded a high protein, high lysine wheat protein concentrate. The yield of concentrate improved with increases in the pH of extraction. A pH 12.5 extraction yielded isolates containing 80.04% protein from bran and 88.09% protein

from shorts. The nutritive quality of bran protein concentrate ranked high compared to soy and other wheat components. Wheat protein concentrate from bran had a PER value of 2.07 and a high (89.9%) digestibility value.

4. Wu, Y.V. and Sexson, K.R. 1975. Preparation of protein concentrates from normal-and high-protein wheats. J. Agric. Food Chem. 23:5, 903-905.

Abstract: An alkaline extraction process was developed to produce protein concentrates from high-and normal-protein wheats. Different solvents, various pH values, wheat-to-solvent ratios, and particle size of wheat were studied. Optimum extraction was at pH 10.8 in 0.03 N sodium hydroxide with 100 g of wheat per 600 ml of solvent. After centrifugation each of two alkaline extractions was adjusted to pH 6 to yield a precipitate and a supernatant. Bran was removed from starch and protein by screening the second alkaline dispersion. The protein content (nitrogen x 5.7) of the concentrate varied between 83% and 92%, depending on particle size and protein content of the wheat used, and accounted for 52% to 64% of the total wheat protein. Prime starch (0.3% protein) was also produced in good yield. Higher yields of protein were obtained from wheat containing higher protein.

5. Wu, Y.V. and Sexson, K.R. 1975. Composition and properties of protein concentrate from normal and high-protein wheats. J. Agric. Food Chem. 23:5, 906-909.

Abstract: Protein concentrates and by-products produced from ground wheat were analyzed for amino acid composition, protein, starch, fat, fiber, ash, and various neutral carbohydrates. The concentrates contained from 83% to 92% protein (nitrogen x 5.7), 2.1 to 2.6 g of lysine, 2.5 to 3.5 g of total sulfur amino acids per 16 g of nitrogen, 1.5% to 7.4% fat, 0.9% ash, and from 1.8% to 3.9% total carbohydrate. Protein concentrate had a nitrogen solubility of 97% at pH 2.5 and a minimum solubility of 5.5% at pH 6.2, a hydration capacity of 2.6, had an emulsion stability of 63%, and formed a reasonably strong and elastic gluten ball.

D. Miscellaneous grain proteins

1. Balmaceda, E. and Rha, C.K. 1974. Spinning of zein. J. Food Sci. 39:2, 226-229.

Abstract: An experimental study of the variables in the wet spinning process for zein is presented. The results indicate conditions at which spinning of zein is possible and a spinnability curve, which shows the region where spinning is possible, has been defined. The spinnability curve tends to be higher for larger extrusion velocities, lower dope concentrations, higher bath temperatures, and larger spinnerette diameters.

2. Balmaceda, E. and Rha, C.K. 1973. The rate of coagulation of zein. J. Food Sci. 38:4, 905-906.

Abstract: The rate of coagulation of protein dope (zein in 95% alcohol) in HCL constant temperature coagulating bath (pH 3) was determined experimentally. Data were analyzed assuming diffusion controlled coagulation, and values of a parameter called diffusion velocity, which adequately describes the boundary advancement, were obtained.

3. Connor, M.A. and Saunders, R.M. and Kohler, G.O. 1976. Rice bran protein concentrates obtained by wet alkaline extraction. Cereal Chem. 53:4, 488-496.

Abstract: Protein concentrates were extracted from full-fat rice bran with dilute sodium hydroxide at $24^{\circ}C$, followed by separation of the fibrous residue, and heat or acid precipitation of the extracted protein. In an alternate procedure, the starch fraction was separated prior to protein precipitation. Protein concentrates containing 23-31% protein, 33-48% fat, and 15-23% starch were obtained in yields of 14-20%. Protein concentrates with the bulk of the starch removed contained 33-38% protein and 49-55% fat. Fats were 86% unsaturated. Protein efficiency ratio and nitrogen digestibility of the concentrates were significantly greater than those of the starting bran. Nitrogen solubility curves, amino acid profiles, fatty acid composition, and mineral content of the concentrates are reported, as well as yield and composition of by-products produced during the process. Alkaline extraction of commercially defatted rice bran is also reported.

4. Harden, M.L., Stangland, R., Briley, M. and Yang, S.P., 1976. The nutritional quality of proteins in sorghum. J. Food Sci. 41:5, 1082-1085.

Abstract: Phase one of a two-phase project identified lysine and threonine as the first and second limiting amino acids of sorghum in rats. Supplementation of L-lysine · HCl at the 0.4% level to sorghum diets fed to rats at the 10% protein level (N x 6.25) resulted in increased weight gain; the addition of threonine caused further gain. No improvement in weight gains of rats was noted when methionine, tryptophan or isoleucine was added. In

phase two, when the proteins in sorghum were compared with those in corn or wheat as the sole source of dietary protein at the 8.0% crude protein level, nutritional values of the proteins were found to be similar. With soybean oil meal supplementation and fed at the 8.0% crude protein level, no significant differences in nutritive value of any of the diets were noted. The biological value of the proteins in sorghum can be improved by supplementation with selected amino acids and by combining with other food sources.

5. Pomeranz, Y. 1973. A review of proteins in barley, oats, and buckwheat. Cereal Sci. Today 18:9, 310-315.

Summary: Composition of barley, oats, and buckwheat is of interest in many areas of the world. The review covers studies conducted over the last four years in the Barley and Malt Laboratory on protein contents and amino acid composition of cultivars and selections, distribution of amino acids within the kernel, and changes during processing of the three commodities. Amino acid balance in proteins of buckwheat, oats, and certain barley cultivars is superior to the balance in proteins of commercially grown major cereal crops.

6. Tsen, C.C. ed. 1974. Triticale, First man-made Cereal. Published by the American Association of Cereal Chemists, St. Paul , Minn.

Summary: This publication is a complete review of the development, biochemistry, structure, nutrition and possible uses of triticale. Triticale, a genetic blend of wheat and rye will probably see its first food uses in bread making. The presence of lysine from the rye will make triticale a more complete protein than either rye or wheat by itself.

7. Wells, G.G. 1976. The role of dry milled cereal products in fabricated foods. Cereal Foods World 21:1, 14-16.

Summary: Rice flours have the lowest level of proteins of the cereal flours; they are also low in fat. Corn, sorghum, and barley are good sources of protein but oat flour is the best. For the most part cereal grains are deficient in lysine, thus they combine well with soy flour which is high in lysine.

8. Wu, Y.V., Sexson, K.R. and Wall, J.S. 1976. Triticale protein concentrate: preparation composition and properties. J. Agri. and Food Chem. 24:3, 511-517.

Abstract: An alkaline extraction process gives protein concentrates and starch from ground triticale. Optimum extraction was at pH 10.8 in 0.05 N sodium hydroxide with 150 g of triticale per 900 ml of solvent. The triticale was extracted twice with sodium hydroxide solutions. After centrifugation

each of two alkaline extractions was adjusted to pH 4.6 to yield a precipitate and a supernatant. Bran was removed from starch and protein by screening the second alkaline dispersion. Protein content (nitrogen x 5.7) of the concentrates varied between 82% and 87%, depending on the amount in the original grain, accounted for 53% to 59% of total triticale protein, and had from 3.2 to 3.3 g of lysine and 3.5 to 3.8 g of total sulfur amino acids per 16 g of nitrogen. Minumum nitrogen solubility of the concentrates was 8% to 9% near pH 6, and solubility was 70 to 83% at pH 2.3. All protein concentrates had good functionality relative to their hydration capacity (near 4), emulsifying activity (near 90%), and emulsion stability (around 85%).

VI. Novel proteins

Novel proteins, or proteins from unconventional sources, have been the subject of much investigation. In the plant field, leaf protein concentrate has received much interest. Various legumes and other plants not previously described in this report are also being researched as sources of protein extenders. The use of novel proteins as extenders is potentially feasible, but they probably will not be ready for human consumption in the near future.

A. Leaf proteins

1. Betschart, A.A., 1976. Leaf protein: nutritional and functional potential in the human diet. Presented at the 61st annual meeting of the American Association of Cereal Chemists, New Orleans, La. Oct 5-8, 1976.

Abstract: The technology for isolating unfractionated leaf protein has been available for several decades. Although leafy crops produce more protein than any other agricultural commodity, leaf protein concentrate (LPC) has gained only limited acceptance in the human diet. A critical examination of the nutritional and functional properties of unfractionated (green) and heat fractionated (cream colored) LPC and their relationship to the current needs of the human dietary will be developed. The influence of such variables as preparation, isolation and drying methods upon nutritional and functional properties will be analyzed, with the optimum combinations of these methods defined to attain various functional and nutritional criteria. The potential role of LPC as a major source of nutrients and as a component in cereal-based diets will be examined.

2. Betschart, A.A. and Kinsella, J.E., 1973. Extractability and solubility of leaf protein. J. Agric. and Food Chem. 21:1, 60-65.

Abstract: A laboratory-scale extraction method was developed which maximized the extraction of leaf protein while minimizing the possibility of denaturation. The method consisted of homogenizing leaves in a micromill at 6^{o} with 0.1 M Tris buffer, pH 7.4 containing 0.5 M sucrose, 7.5 mM ascorbic acid, 6.6 mM cysteine HCl, and 14.2 mM mercaptoethanol. Protein (TCA insoluble) nitrogen equivalent to 60.8% of total leaf nitrogen was extracted from alfalfa leaves by this method. The protein content of cowpea, peanut, and soybean leaves was also investigated. The solubility of total and protein nitrogen of soybean leaf extracts was studied as a function of pH. Both the total and protein nitrogen were most soluble at pH 2.0 and 6.0 and above. Minimum solubility occurred between pH 3.2 and 3.7.

3. Betschart, A.A. and Kinsella, J.E., 1974. Influence of storage on composition, amino acid content and solubility of soybean leaf protein concentrate. J. Agric. Food Chem. 22:116.

Abstract: Soybean leaf protein concentrate (LPC) was prepared by either acid (LPC pl) or heat (LPC Δ) precipitation. Freshly prepared, freeze-dried LPC pl contained 1.55% moisture, 10.92% nitrogen, and 9.60% lipid, whereas LPC Δ contained 2.67% moisture, 11.80% nitrogen, and 8.19% lipid. With the exception of the limiting amino acid methionine, the amino acid profile compared favorably with the FAO reference protein. LPC was virtually insoluble in water adjusted from pH 1.50 to 11. LPC pl was 60% soluble at Ph 2.0 and 10.0 and above but 10% soluble from pH 3.5 to 6.8. Samples of both LPC preparations were stored for up to 24 weeks at 27^{o} in the presence of oxygen. There was significantly more isoleucine, leucine, and lysine in LPC Δ, whereas LPC pl contained more glutamic acid, glycine, and histidine, irrespective of storage time. Methionine, glutamic acid, and tyrosine varied significantly during storage; only tyrosine, however, exhibited a linear trend. Solubility profiles were not influenced by storage.

4. Betschart, A.A. and Kinsella, J.E., 1975. Changes in relative concentration of fatty acids in stored soybean leaf protein concentrate. J. Food Sci. 40:1, 271-273.

Abstract: The stability of lipids associated with soybean leaf protein concentrate (LPC) during storage at 27^{o}C was studied for periods of up to 24 weeks. The relative concentration of fatty acids was determined at 4-week intervals. LPC lipids were relatively stable for up to 8 weeks. After 12 weeks of storage, however, linolenic acid decreased 18% and palmitic acid increased 10% over their respective controls. The deleterious changes which occurred in the lipids of freeze dried LPC stored under relatively mild conditions emphasizes the importance of prudent selection of storage conditions to preserve nutritive value and acceptability.

5. Edwards, R.H., Miller, R.E., de Fremery, D., Knuckles, B.E., Bickoff, E.M. and Kohler, G.O. 1976. Pilot plant production of an edible white fraction leaf protein concentrate from alfalfa. J. Agric. Food Chem. 23:4, 620-626.

Abstract: This paper describes the development of a pilot plant scale wet fractionation process to obtain an edible white protein fraction from fresh alfalfa (Medicago sativa L.). Expressed alfalfa juice is given a flash heat treatment to agglomerate preferentially the green pigmented proteins which can then be separated by continuous high-speed centrifugation. The chlorophyll-free soluble protein remaining in the supernatant is precipitated by heating to 80^{o} and separated by centrifugation. An off-white to light-tan, bland, protein concentrate containing approximately 90% protein is obtained. The product and its processing behavior can be improved by the addition of sodium metabisulfite to the fresh alfalfa prior to processing. The major product from the process, called the Pro-Xan II process, is a dehydrated alfalfa meal. The remaining products include the alfalfa solubles fraction and a feed-grade protein-xanthophyll concentrate. The latter is prepared by heat coagulating, pressing, and drying the agglomerated green protein fraction. Yields, compositions, and other processing data from the pilot plant operation are discussed.

6. Hood, L.L. and Brenner, J.R., 1975. Compositional and solubility characteristics of alfalfa protein fractions. J. Food Sci. 40:6, 1152-1155.

Abstract: Leaf protein concentrates represent potential sources of human food; however, their compositional, nutritional and functional characterization have been fairly limited and require further elucidation in anticipation of their utilization in food systems. Protein content of alfalfa tissue and extent to which it can be extracted varies significantly with agronomic conditions, leaf-to-stem ratio, age at time of harvest, time from harvest to processing, extent of masceration and expression, and extraction conditions. This paper presents results of an investigation on compositional and solubility properties of protein-rich fractions obtained from fresh alfalfa tissue by extraction in buffered solution.

7. Kohla, G.O. and Knuckles, K.E., 1976. Edible protein from leaves. Presented at the 36th annual meeting of the Institute of Food Technologists, Anaheim, Calif. June 6-9, 1976.

Summary: To be used as a protein source, leaf protein isolates or concentrates must be made competitive economically with soy. Whole green leaf protein concentrates have been unacceptable because of their color and flavor characteristics. A method for separating the protein into two fractions is discussed. One faction contains green protein rich in carotene and xanthophyll and could be used as a poultry supplement while the white faction could be used for humans. This paper has an extensive reference list on leaf proteins.

8. Lu, P.S. and Kinsella, J.E., 1972. Extractability and properties of protein from alfalfa leaf meal. J. Food Sci. 37:1, 94-99.

Abstract: Several factors affecting the extractability of proteins from alfalfa (Medicago sativa) leaf meal prepared at 150°C and 75°C were investigated. The optimum conditions for extraction of the proteins were pH 12, 70°C for 30 min. using a solvent-to-meal ratio of 20:1. The alkaline extracted protein was precipitated by acid at pH 3.5. The protein from high temperature treated meal was less extractable: 9 mg vs. 30 mg/% in low-heat meal; the leaf protein was least soluble between pH 3-5. Maximum solubility occurred below pH 2 and above pH 6. The sodium proteinate was more soluble at acidic pH values. Leaf protein formed gels at pH 11 and 12 in the presence of 2.0% calcium salt. With 0.5 carrageenan the sodium proteinate formed gels at pH 7.5. The extracted protein had a balanced amino acid composition with the exception of methionine which was low. Heating decreased the lysine content of leaf proteins.

9. Wang, J.C. and Kinsella, J.E., 1976. Functional properties of novel proteins: alfalfa leaf proteins. J. Food Sci. 41:2, 286-288.

Abstract: Functional properties of protein concentrates from alfalfa leaves (ALP) prepared by several methods were determined. Minimum solubilities occurred around pH 3.5-4; sodium chloride 0.05-0.2 M had little effect on minimum solubility. Extraction of the lipids from ALP with acetone decreased solubility slightly; increased the bulk density (2-3 fold); and reduced water and fat absorption capacities by 50% compared to the controls. Both emulsifying activities and emulsion stabilities of ALP samples were generally better than those of soy protein concentrate but poorer than those of soy sodium proteinate; i.e., average of 57, 48, and 87 and 60, 50, and 90%, respectively. Emulsifying capacity of ALP samples were reduced following acetone extraction.

10. LPC. Untapped protein reserve, 1975. Food Processing. 36:7, 39-41.

Summary: Leaf protein concentrate is potentially the most attractive way of supplementing cereal and meat products. At present it is unacceptable because of its high fiber content and unacceptable flavor. A Pro-Xan II process is being developed to form a white LPC powder which is approximately 90% protein and can be used as a meat extender in ground meats, sausages, and fabricated meats.

B. Legume proteins

1. Karakoltsides, P.A. and Constantinides, S.M., 1975. Okra seeds; a new protein source. J. Agric. Food Chem. 23:6, 1204-1207.

Abstract: Okra seed was investigated for the first time for its potential as a seed protein. Chemical and nutritional studies were carried out to evaluate the seed and compare it to other seed proteins such as soya, cottonseed, etc. One variety (Emerald) of okra seeds was used throughout the study. All determinations were carried out on the whole seed including the seed coat and endosperm. The amino acid composition of okra seed was found to be similar to that of soybeans, yet the PER value was higher for okra seed. Rats fed on zein as a source of protein failed to grow. When the rats resumed a diet of casein or okra, a regular rate of growth resumed.

2. Kon, S., Wagner, J.R. and Booth, A.N., 1974. Legume powders: preparation and some nutritional and physiochemical properties. J. Food Sci. 39:5, 897.

Abstract: Since beans and leguminous seeds--desirable sources of protein--take a long time to prepare in the regular fashion (soaking overnight), an alternative might be to process them into precooked powders for use as ingredients in convenience foods. Grinding treatments that break most or all of the cells and release cell contents of raw legumes prevent the subsequent development of the characteristic cooked-bean flavor. An off-flavor develops when ground raw legumes are suspended in water, but this can be controlled by adjusting the pH of the slurry. Methods are described for preparing two kinds of legume powders using small white and pinto beans. Other beans can be used also: Great Northern, Sanilacs, garbanzo, fava, lima beans, lentils, Austrian winter peas, and garden peas. The thiamin, niacin, pyridoxine, and folacin content of the powders was analyzed. Only folacin was affected to any extent by processing. Both powders were free-flowing, non-hydroscopic, and convenient to use, and both also reconstituted well.

3. Liener, I.E., 1976. Legume toxins in relation to protein digestibility. J. Food Sci. 41:5, 1076-1081.

Abstract: Proteins capable of inhibiting the proteolytic activity of digestive enzymes are common constituents of legumes. These protease inhibitors are generally believed to be largely responsible for the poor digestibility of the protein of legumes which have been inadequately cooked. This reduction in digestibility is invariably accompanied by an enlargement of the pancreas. Recent studies in the author's laboratory, however, have revealed that only about 40% of the growth-depressing activity and a similar fraction of the pancreatic hypertrophic effect of unheated soybeans can be attributed to the action of the trypsin inhibitors. The poor digestibility and pancreatic hypertrophy that cannot be accounted for by the trypsin inhibitors are most likely the consequence of the refractory nature of the undernatured protein to attack by trypsin. The

phytohemagglutinins also play an important role contributing to the poor nutritive value of some legumes, particularly those belonging to the genus Phaseolus. In this case the phytohemagglutinins are believed to exert a nonselective adverse effect on the absorption of nutrients from the intestinal tract rather than a direct effect on the digestive process.

4. Maneepun, S., Luh, B.S., and Rucker, R.B., 1974. Amino acid composition of biological quality of lima bean protein. J. Food Sci. 39:1, 171-174.

Abstract: The proteins in dry large lima beans (Phaseolus lunatus, L. var BC_6) were extracted at pH 7.2 with a 0.1 M phosphate buffer, and then precipitated at pH 5.0 after acidification with phosphoric acid and heating at 100°C for 10 min. The freeze-dried product contained 54.3% protein. The amino acid content of whole large lima beans and the freeze-dried lima bean protein concentrate (LPC) were determined in a Technicon amino acid analyzer after acid hydrolysis of the proteins. The nutritive value of the LPC was determined by feeding to male albino rats for 21 days, using casein and soybean protein as references. It was found that LPC was low in methionine, lysine, phenylalanine and valine. When LPC was fortified with 0.5% methionine, 0.3% lysine, 0.5% phenylalanine and 0.3% valine, and then fed to the albino rats in an otherwise normal diet containing 10% protein, the nutritive value of the LPC was as good as that of the casein standard. The freeze-dried LPC has a protein efficiency ratio (FER) of 1.68 $\pm$ 0.07, feed efficiency ratio (FER) of 5.94 $\pm$ 0.25, and net protein utilization (NPU) value of 48.41 $\pm$ 0.03, and increased the NPU to 72.70 $\pm$ 3.38. The importance of essential amino acids to nutritional value of bean proteins is discussed.

5. Manrique, J. and Thomas, N.A., 1976. The effect of lupin protein isolation procedures on the emulsifying and water binding capacity of a meat-protein system. J. Food Techn: 1 IFST (U.K.) 11:4, 409-422.

Abstract: A study on the emulsifying capacity and water binding capacity of lupin protein (isolates and concentrates) using various isolation procedures was carried out. These procedures included protein extraction in single or double step in alkaline or acid conditions by the use of a wet or dry milling technique. Different ion conditions were also used. For comparison, soya bean and lupin protein were extracted through a co-precipitation procedure. Protein extraction by wet milling and then precipitation and dry at isoelectric pH promoted water binding capacity, while drying milling and alkaline extraction enhanced the emulsifying capacity. Protein co-precipitation and ion environmental conditions are other factors influencing the emulsifying capacity and water binding capacity. The proper choice of these parameters will determine the optimum conditions for emulsifying and water binding capacity of a protein isolate or concentrate.

6. Molina, M.R., Argueta, C.E. and Bressani, R., 1976. Protein-starch extraction and nutritive value of the black-eyed pea and its protein concentrates. J. Food Sci. 41:4, 928-932.

Abstract: The processes were developed for the preparation of protein concentrates with a concommitant recuperation of the starch fraction from the Black-eyed pea (Vigna sinensis). The first was a one-stage extraction process using a 4:100 peeled meal: solvent ratio, a pH of 9.0, and 25^{o}C, and the second a two-stage process of 1 hr per stage using a peeled meal:solvent ratio of 12:100, pH of the suspension 6.8, and 25^{o}C. Protein extraction efficiencies of 87% and 86% for the one- and two-stage processes, respectively, were not improved by increasing either extraction time or temperature (up to 50^{o}C). The starch recuperation was 84% in the former and 76% in the latter. Both protein concentrates (66%-70% protein) obtained by isoelectric point precipitation proved to have a higher methionine and cystine content and a higher PER value than the original peeled meal. Preliminary results indicate the suitability of the protein concentrates for use in the formulation of pasta products, sausages, and tacos.

7. Onayemi, O. and Potter, N.M., 1976. Cowpea powders dried with methionine: preparation storage stability. Organaleptic properties, nutritional quality. J. Food Sci. 41:1, 48-53.

Abstract: Cowpea (Vigna sinensis) was soaked, dehulled, ground, supplemented with various levels of DL-methionine, drum dried and the powders evaluated fresh and after storage. Chemical determinations indicated that the protein, amino acid composition, available lysine, methionine retention and thiamine content of the powders, compared to raw cowpeas, were not appreciably affected by the processing and storage conditions, including 24 weeks at temperatures up to 37^{o}C. Fresh and stored powders supplemented with up to 0.6% methionine were evaluated in a traditional moin-moin recipe by a taste panel of members from several African countries and well rated in terms of color, flavor, consistency and overall acceptability. Nutritional studies indicated that drum drying eliminated trypsin inhibitors and that methionine supplementation produced a concentration dependent effect on protein quality as gauged by weight gains of rats and PER values, which increased from 1.64 without methionine supplementation to 2.65 at the 0.6% addition level. At the 0.6% level, however, fatty infiltration of rat livers occurred. This was also evident but much less pronounced at a level of 0.4% added methionine. Cowpea powders stored 24 weeks showed reductions in PER values but even at 37^{o}C protein quality, as measured by PER, was largely retained in methionine-supplemented powders.

8. Ruiz, L.P., Jr. and Hove, E.L., 1976. Conditions affecting production of a protein isolate from lupin seed kernels. J. Sci. Food Agric. 27:7, 667-674.

Abstract: Conditions were investigated to determine the optimum processing parameters for preparation of a protein isolate from the ground, dehulled lupin seeds of *Lupinus angustifolius*. The extraction variables were: particle size (16-100 mesh); pH (2-11); extraction medium; solvent to lupin ratio (10:1 to 40:1); temperature (20-60°C) and time (15-60 min). The isoelectric point of the lupin protein was found to be pH 4.5 with a protein solubility of greater than 90% above pH 8.0. Using 60-100 mesh ground lupin and extracting at pH 8.5 for 30 min., a protein isolate was obtained on acidification to pH 4.8 which was 89.4% protein compared to 34.0% protein for the original dehulled lupin. This protein isolate represented 19.8% of the starting material and 52% of the starting nitrogen. Similar results were also obtained when hexane defatted lupin was used. In this case the protein isolate had a protein content of 92.5%. The yield of protein isolate could be increased to 25.7% of the starting material if the extraction was repeated. The protein efficiency ratio for the protein isolate was 2.90 when supplemented with methionine.

9. Sarwar, G., Sosulski, F.W. and Bell, J.M., 1975. Nutritive value of field pea and fababean proteins in rat diets. Can. Inst. of Food Sci. and Tech. 8:2, 109-112.

Abstract: The nutritive values of field pea, fababean and soybean proteins were evaluated alone and in blends with wheat flour and essential amino acids. Differences in feed intake, weight gain, true protein digestibility (TPD) and protein efficiency ratio (PER) paralleled the levels of sulfur amino acids in the legumes and casein, and ranked the diets in the order; casein, soybean, field pea, fababean. Methionine supplementation of the legumes increased the feed intakes of the diets to the level of casein and substantially improved the weight gains, TPD, and PER, especially fababean. According to the chemical score, lysine was the limiting amino acid in the legume-wheat blends, and field pea- and fababean-wheat blends were equivalent to the soybean-wheat blend in feed intake, rat growth and protein utilization. Supplementation of the blends with lysine, methionine and threonine resulted in uniformly high levels of feed intake, weight gain, TPD and PER, although the PER for the fababean-wheat blend was significantly below those of the other legume blends. While soybean was the superior legume as the sole source of protein in these rat experiments, the order of weight gains and PER in the wheat blends and amino acid supplementation treatments was field pea, soybean, fababean. Chemical scores gave excellent prediction of feed intake, weight gain and PER but not TPD. Fababean proteins, even when supplemented with methionine, were low in protein digestibility.

10. Satterlee, L.D., Bembers, M. and Kendrick, J.G., 1975. Functional properties of the Great Northern Bean (*Phaseolus vulgaris*) protein isolate. J. Food Sci. 40:1, 81-84.

Abstract: Extraction of Great Northern beans (*Phaseolus vulgaris*) with a NaCl solution yields a high protein powder (Bean Protein Concentrate-BPC). The BPC is composed of 65% globulins and 35% albumins. The emulsion capacity of the albumins is good, as is the foam stability. The globulins possessed the best foaming ability, although being poorer than the albumins in foam stability. When the BPC was added to white bread at high levels, a major decrease in loaf volume occurred. Addition to a soft wheat flour cookie formulation improved the spread of the cookies during baking.

11. Sosulski, F. and Garratt, M.D., 1976. Functional properties of ten legume flours. Can. Inst. of Food Sci. and Tech. 9:2, 66-69.

Abstract: The functional properties of ten legume flours including undenatured soybean flour were evaluated by laboratory tests for nitrogen solubility, water and fat absorption, emulsification, whippability, viscosity and gelation. Soybean and lupine flours which contained high proportions of protein but no starch showed excellent water absorption, fat absorption and whipping properties. Soybean and lima bean flours were superior in oil emulsification while chickpea showed good whippability and foam stability. Slurries of high starch flours such as lentil, lima bean, mung bean and chickpea gave high peak and cold viscosities in the viscoamylograph curve. Great Northern bean, pea bean and fababean showed promising gelation characteristics. Flour which contained pigments that would limit their utility in aqueous food systems included lupine, fababean, mung bean, field pea, lentil and soybean.

12. Vaisey, M., Tassos, L., McDonald, B.E. and Youngs, C.G., 1975. Performance of fababean and field pea protein concentrates as ground beef extenders. Can. Inst. of Food Sci. and Tech. J. 8:2, 74-78.

Abstract: Broiled meat patties (70% ground beef, 10% legume and 20% water), containing high protein concentrates from dehulled, pinmilled fababeans and peas, were judged more acceptable by a panel of 90 untrained subjects when the concentrates were added in the form of texturized flakes produced by drum-drying than when they were added in the form of flour. Meat patties containing either fababean or pea flakes were comparable in acceptance to those containing a texturized soy product although all were liked less than the 100% beef control. Cooked patties containing fababean and pea protein concentrates were softer than beef-soy and control patties as shown by Allo-Kramer shear values. Drip loss from each legume-beef mixture was approximately half that from the control. All cooked patties, however, were similar in proximate composition. Examination of patties prepared with 3 levels of legume replacement of beef and 3 legume:water ratios at each level showed that fababean and pea protein concentrates had similar effects on the firmness of raw and cooked patties, cooking losses, fat and moisture retention. Texturizing fababean and pea concentrates reduced fat retention making cooked patties containing them more like the beef control.

C. Miscellaneous novel proteins

1. Betschart, A.A. 1974. Nitrogen solubility of alfalfa protein concentrate as influenced by various factors. J. Food Sci. 39:4, 1110-1115.

Abstract: Conditions which influence nitrogen solubility of cream-colored Alfalfa Protein Concentrate (APC) prepared from heat fractionated alfalfa juice were investigated. Solubility decreased with increasing concentration of APC and increasing ionic strength. Reducing, disulfide splitting and surface active agents had little influence on APC solubility. Precipitation of the protein concentrate by acid (HCl, pH 3.5) rather than heat ($80^{\circ}C$) and alkali treatment of APC prior to freeze drying enhanced solubility. The method described for determining nitrogen solubility required less sample (100 mg), showed less pH drift than other methods and values obtained compared favorably with the Nitrogen Solubility Index and Protein Dispersibility Index.

2. Hensarling, A.P., Jacks, T.J. and Booth, A.N., 1973. Cucurbit seeds: Nutrition value of storage protein isolated from cucurbita foetidissima (buffalo gourd). J. Agric. Food Chem. 21:6, 986-987.

Abstract: The storage globulin of Cucurbita foetidissima H. B. K. seed was isolated and evaluated nutritionally. Arginine, aspartic acid, and glutamic acid were the most abundant amino acids. Ratios of the content of each essential amino acid to the content of total essential amino acids indicated that lysine, cysteine, and tryptophan were low and methionine and isoleucine were borderline. With respect to total protein nitrogen furnished by essential amino acids, the globulin was between soybean protein and proteins of cottonseed, sunflower, and peanut. The corrected protein efficiency ratio was 1.66 compared with casein at 2.50 g of weight gain of weanling rats per gram of protein intake. In these respects, C. foetidissima globulin resembled globulins of other oilseeds.

3. Knuckles, B.E., de Fremery, D., Bickoff, E.M. and Kohler, G.O. 1975. Soluble proteins from alfalfa juice by membrane filtration. J. Agric. Food Chem. 23:2, 209-216.

Abstract: After removing the green chloroplastic protein from fresh alfalfa juice, ultrafiltration and/or diafiltration was used to prepare a soluble, cream-colored protein concentrate. Ultrafiltration was useful in concentrating the protein by removing 80% to 90% of the water and nonprotein components. Continuous diafiltration removed additional quantities of nonprotein components yielding a clear, stable protein solution. The purified protein, when precipitated at $25^{\circ}C$ and pH 4.8, redissolved on adjustment of pH (3.5 or 7.0). Freeze drying of the purified protein solution having a pH of 7 yielded a product of about 93% protein which could be readily redissolved in water.

4. Meifan, T. and Deyoe, C.W.., 1976. Nutritive value of buffalo gourd (*Cucurbita foetidissima*) seed protein. Presented at the 61st annual meeting of the AACC. New Orleans, La. Oct. 5-8, 1976.

Abstract: Buffalo gourd seeds, *Cucurbita foetidissima*, are protein and oil-rich seeds, and could be grown as a food crop in arid lands. In this investigation, buffalo gourd seed flour (70% protein) was prepared, and the nutritive value studied by rat growth and PER determination. Comparisons were made with soybean protein and casein. Limiting essential amino acids were studied by supplementation of the deficient amino acids (lysine, threonine, methionine, and isoleucine) calculated from amino acid data. Differences between soybean meal protein and gourd seed protein were nonsignificant. Supplementation of gourd seed protein with lysine and threonine resulted in highly significant responses in growth, PER, and resulted in performance similar to casein control.

5. Miller, R.E., de Fremery, D., Bickoff, E.M., and Kohler, G.O. 1975. Soluble protein concentrate from alfalfa by low temperature acid precipitation. J. Agric. Food Chem. 23:6, 1177-1179.

Abstract: A soluble protein fraction was obtained from chloroplast-free alfalfa juice (prepared by centrifugation of flash-heated whole juice) by precipitation at pH 3.5 and 2^{o}. To retain the solubility, it was also necessary to maintain this temperature during washing at pH 3.5 and redissolving at pH 7. Acid precipitation at higher temperatures yielded protein with reduced solubility. The low-temperature fraction contained about 70% protein and could be concentrated to about a 6% solution. When freeze dried, the protein could be redissolved at room temperature, even after storage for several months at ambient temperatures.

VII. Protein Blends

Blends of textured plant proteins are receiving much attention for several reasons. The most important is that a combination of plant proteins limited in one or more amino acid, gives a synergistic effect to the PER value. For example, when soy, which is deficient in methionine, is combined with wheat, which is higher in methionine but deficient in lysine, a PER value greater than either soy or wheat alone results. Different functional properties may be possible when various proteins are combined. It is also suggested that one can use a greater amount of extender in blended protein products by using each protein at a level in which no off-flavors are detectible. Blends of plant proteins are being researched as well as blends of plant proteins and proteins from non-plant sources.

1. Castro, C.E., Yang, S.P. and Harden, M.L., 1976. Supplemental value of liquid cyclone processed cottonseed flour on the proteins of soybean products and cereals. Cereal Chem. 53:2, 291-298.

Abstract: Studies were conducted to determine whether supplementation with cottonseed flour produced by a liquid cyclone process (LCP) would improve the protein quality of soy concentrate (soy 70 HS, 70 LS), soy isolate (soy 90 HS, 90 LS), triticale, wheat, and rye. When compared with the FAO/WHO suggested pattern, all the soybean products and cereals contained more essential amino acids than the requirements for the adult human, whereas the total sulfur amino acids of soy 70 HS and 90 HS and the lysine of triticale, wheat, and rye do not meet the requirements of either the infant or school child. In Experiment One, young rats were fed in otherwise adequate but protein-free diet, or the same diet supplemented with 10% protein (N x 6.25) from casein, LCP cottonseed flour, soy concentrate, soy isolate, triticale, wheat, or rye. Average weight gain of the rats receiving a 10% LCP cottonseed protein diet was significantly greater than that of the rats receiving any other experimental diet. The protein efficiency ratios (PER) of casein and cottonseed were similar but higher than for all other diets. In Experiment Two, rats were fed diets containing 5% protein from LCP cottonseed flour, and 5% protein from one of the above soy products or cereals. The PER values for the diets containing 5% protein from cottonseed and 5% protein from soy concentrate, soy isolate, triticale, or wheat were significantly greater than those for the comparable diets containing 10% protein from soy products or cereals alone. The significant improvement in the protein quality of soy concentrate, soy isolate, triticale, and wheat suggests that LCP cottonseed flour is a valuable supplement to these and possibly to other grain products.

2. Conway, H.F. and Anderson, R.A., 1973. Protein fortified extruded food products. Cereal Sci. Today. 18:4, 94-97.

Abstract: Mixtures of yellow-corn snack grits with four high-protein products, and five other starchy materials with soy flakes, were processed in a high-temperature short-time extruder. These extruded products are completely cooked and have potential as a base for gruel or soups; as a beverage, especially if sweetened and flavored, and after coating with oil and adding seasoning, as a high protein snack item.

3. Yeo, Y. and Bates, R.P., 1973. Consistency of aqueous soybean-rice mixtures. J. Food Sci. 38:6, 1145-1148.

Abstract: The influence of formulation, thermal processing and storage duration on the consistency of processed aqueous soybean-rice mixtures was studied. The mixtures were thermally processed achieving a sterilizing F_o value of 15 min. Soybean:rice ratio exerted a large influence on the consistency of processed and unprocessed mixtures. Increased viscometric constants ("n", "K") and apparent viscosities (U_a) were obtained as the mixtures contained larger amounts of soybeans. Addition of fish protein concentrate (FPC) to the aqueous mixtures resulted in increased thickening of the homogenates. Thermally processed homogenates exhibited much higher apparent viscosities than those obtained by the addition of FPC. Processed samples thickened upon storage. Homogenate prepared from 1:1 soybean-rice mixture with added FPC would be more suited as a weanling food than that prepared from 3:1 mixture.

4. Protein source combinations, 1975. Food Processing. 36:4, 52-54.

Summary: Increased emphasis is being placed on combinations of proteins. Impetus has been gained from new sources of high protein flour from cereal grains and oil sources: corn germ, cottonseed, wheat gluten, and oats concentrate. All were predicted to be in commercial production in 1976. Advantages of using combinations include (1) increased PER value, (2) potential of permitting higher use levels, (3) flavor improvement, (4) texture changes, and (5) better protein availability.

5. Research of nutrition of meat and extender blends show PER of mixture close to that of lean beef. 1975. Food Product Development. 9:3, 72-74.

Summary: Studies at the USDA Eastern Regional Research Center show that blends of lean beef with proteins from meat by-products, whey, fish, soy, and cottonseed can be made without lowering the PER below that of casein (2.5). Collagen was also evaluated to observe its textural effect, and it was found that if another protein affected the product's texture adversely, collagen could restore it to its natural level. Tests showed that whey, fish, soy, or cottonseed protein products could be added to beef in levels as high as 30%.

6. Rice-textured soy blend has 18% protein content, PER of 2.5+, 1976. Food Processing. 37:5, 60-61.

Summary: A rice protein product has been produced which is a vitamin-fortified combination of rice and specially processed textured soy protein. The synergistic effect of blending gives a PER of over 2.5. The soy protein appears to constitute about 25% of total mixture by dry weight.

7. Textured vegetable protein with PER equal to 96% of casein. 1975. Food Processing. 36:9, 40.

Summary: A textured vegetable protein product manufactured from a blend of 80% soy flour and 29% vital wheat gluten has a protein content of 52% with a PER of 2.4. In producing the textured protein blend by combining protein from two sources, improved quality can be obtained and a lower quantity may be used.

8. Triticale concentrate has 87% protein. Soy/triticale protein blend has theoretical 2.5 PER. 1975. Food Processing. 36:11, 34-35.

Summary: Adjusted PER of triticale protein is 1.5 and of soy protein 2.0 to 2.2. By blending both and taking advantage of the synergistic effect, the theoretical PER could be 2.5. Methionine, one of the limiting amino acids in soy, is abundant in triticale. Flavor is the primary reason for using triticale in formulated foods and bakery goods. Flavor is somewhat similar to rye, therefore, most applications will probably be in cereal and bakery goods.

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